01 SOLID FUELS

Sources, winning, properties

13/01925 Biomarker compounds in ash from coal combustion in domestic furnaces (Upper Silesia Coal Basin, Poland)

Fabiańska, M. J. *et al. Fuel*, 2012, 102, 333–344.

Organic compounds occurring in coal ash of known mineralogy were investigated. Ash came from two domestic furnaces using bituminous coal from the Upper Silesia Coal Basin. Dichloromethane extracts of ash were analysed with gas chromatography–mass spectrometry for biomarkers from fuel and formed during combustion. Distributions of aliphatic hydrocarbons, aromatic and polar compounds were researched. Results were compared with those found for power plant coal ash, coal wastes which underwent self-heating and source bituminous coal. It was found that geochemical features of plant coal ash organic matter reflects mainly geochemistry of source bituminous coal. Several groups of biomarkers such as as *n*-alkanes, steranes and pentacyclic triterpanes show distributions recognizable as coal-deriving what enables to identify source fuel. Values of most biomarker and aromatic hydrocarbon parameters show minor changes due to heat of the combustion process. The most advanced changes are found in distributions of alkylnaphthalenes, pristane, phytane and lighter *n*-alkanes reflected by values of Pr/Ph, Pr/n-C_{17} and Ph/n-C_{18} ratios. Much less extensive changes are seen in distributions of pentacyclic triterpanes which make them the most useful biomarker group for source fuel characterization. Most of biomarkers are probably present in coal ash in unburned coal particles occurring in ash due to low temperature in domestic furnaces favouring organic matter preservation.

13/01926 Coalbed methane sorption related to coal deformation structures at different temperatures and pressures

Pan, J. *et al. Fuel*, 2012, 102, 760–765.

Coal methane adsorption capacity is related to coal deformation structures. Due to different deformation properties and deformation degrees, tectonically deformed coals have different adsorption isotherms and adsorption capacities. In this work, adsorption capacity investigations are performed using three types of tectonically deformed coal (weak brittle deformed coal, strong brittle deformed coal and strong ductile deformed coal) with vitrinite reflectance of about 0.9% at different temperatures and pressures. The results indicate that the methane adsorption capacity in coal has a decreasing relationship with temperature. At a constant temperature, the methane adsorption of different tectonically deformed coals also varies. For example, the strong-ductile deformed coal has a significantly higher adsorption capacity than the weak-brittle deformed coal and the strong-brittle deformed coal at a constant temperature of 30 °C. At low pressures, the strong-brittle deformed coal has a higher adsorption capacity than the weak-brittle deformed coal; as the pressure increases, the adsorption capacities of both types of coal become equal. The findings show that the methane adsorption capacity of different types of tectonic coal is mainly affected by temperature and pressure. At high temperatures (i.e. 50 and 70 °C), the coal samples do not show significant differences in coal methane adsorption capacity, and their adsorption isotherms are similar.

13/01927 Geochemical characteristics of Tertiary coal-bearing source rocks in Xihu depression, East China Sea basin

Zhu, Y. *et al. Marine and Petroleum Geology*, 2012, 35, (1), 154–165.

This study aims at investigating hydrocarbon generation potential and biological organic source for the Tertiary coal-bearing source rocks of Pinghu Formation (middle-upper Eocene) in Xihu depression, East China Sea shelf basin. Another goal is to differentiate coal and mudstone with respect to their geochemical properties. The coal-bearing sequence has a variable organofacies and is mainly gas-prone. The coals and carbonaceous mudstones, in comparison with mudstones, have a higher liquid hydrocarbon generation potential, as reflected by evidently higher HI values (averaging 286 mg HC/g C) and H/C atomic ratios (round 0.9). The molecular composition in the coal-bearing sequence is commonly characterized by unusually abundant diterpenoid alkanes, dominant C_{29} sterane over C_{27} and C_{28} homologues and high amount of terrigenous-related aromatic biomarkers such as retene, cadalene and 1,7-dimethylphenanthrene, indicating a predominantly terrigenous organic source. The source rocks show high Pr/Ph ratios ranging mostly from 3.5 to 8.5 and low MDBTs/MDBFs ratios (<1.0), indicating deposition in an oxic swamp-lacustrine environment. The coals and carbonaceous mudstones could be differentiated from the grey mudstones by facies-dependent biomarker parameters such as relative sterane concentration and gammacerane index and carbon isotope composition. Isotope and biomarker analysis indicate the genetic correlation between the Pinghu source rocks and the oils found in Xihu depression. Moreover, most oils seem to be derived from the coal as well as carbonaceous mudstone.

13/01928 Modeling the effect of humidity on the threshold friction velocity of coal particles

Zhang, X. *et al. Atmospheric Environment*, 2012, 56, 154–160.

In the coal mining industry, large amounts of water are regularly spayed on coal piles to prevent dust emission from the coal particles. The mechanism behind this measure is to manage the threshold friction velocity, which is an important parameter in controlling wind erosion and dust emission. Bagnold has developed a threshold friction velocity model for soil particles. However, the Bagnold model cannot be applied directly to coal particles as coal particles are quite different from soils in physical and chemical properties. The threshold friction velocity of coal particles was studied and modelled under different humidities by using a wind tunnel. Results showed that the effects of humidity on coal particles' threshold friction velocity are related to the hydrophilic effect and adhesive effect. The Bagnold model can be corrected by two new parameter items, which explained the two effects. The new model agreed well with wind tunnel measurements for coal particles with different size categories. Despite the fact the new model was developed for coal particles, its physical basis may allow the model application to other wind susceptible particles.

13/01929 Numerical assessment of coals/blends slagging potential in pulverized coal boilers

Degereji, M. U. *et al. Fuel*, 2012, 102, 345–353.

At this time, the correlation between the existing coal slagging indices and the actual observations made in most conventional boilers is poor. Some of the conventional coal slagging test procedures and the empirical relations they generated, such as, coal fusibility, ash viscosity, silica ratio, percentage of iron oxide in ash, and the ratio of basic to acidic oxides, frequently offer misleading information, especially, when their use is extended to other coals or blends. In this investigation, a CFD code to predict coal ash deposition rates, and a numerical slagging index (NSI) based on the ash fusibility, viscosity and content in coals, have been developed. The two codes have been validated using experimental data on Australian coals. In this paper, the NSI has been tested on wide range of coals and blends, ranging from Indian low-rank coals, to bituminous coals from Australia, Columbia, Indonesia, South Africa, the UK and the USA. The results of predictions correlate well with the reported field performance of the coals and blends, while the results of predictions using some of the existing slagging indices show significant inconsistencies with the experimental data on most of the tested coals. The findings of this numerical investigation provide an encouraging development towards the search for a generic numerical technique of assessing the slagging potential of pulverized coals/blends in boilers.

13/01930 Numerical investigation on performance of coal gasification under various injection patterns in an entrained flow gasifier

Chen, C.-J. *et al. Applied Energy*, 2012, 100, 218–228.

Gasification plays an important role in the development of clean coal technology. To seek appropriate operations for synthesis gas (syngas) formation, the present study develops a numerical method to predict coal gasification phenomena in an entrained-flow gasifier. Particular emphasis is placed on the influence of injection pattern upon syngas production. The parameter of steam/coal ratio is also taken into account to evaluate its impact on hydrogen generation. The simulations suggest that the developed numerical method is able to provide an accurate prediction on syngas formation. With oxygen injected from the centre inlet and coal from the middle ring inlet of the reactor, the operating pattern gives the best performance of coal gasification where the carbon conversion (CC) and coal gas efficiency (CGE) are 89% and 72%, respectively. Increasing steam into the reactor reduces CC and less CO is generated. Nevertheless, more H_2 is produced stemming from water gas shift reaction. This results in slight variation in CGE with altering steam/coal ratio. The obtained results have provided a useful insight into the operation of fuel and oxidant injection for coal gasification.

13/01931 Numerical modeling of Gondwana coal seams in India as coalbed methane reservoirs substituted for carbon dioxide sequestration

Vishal, V. *et al. Energy*, 2013, 49, (1), 384–394.

India has recently witnessed the production of coalbed methane (CBM) on a commercial scale. This research work was carried out to understand and establish the technical feasibility of CO_2-driven enhanced CBM recovery in Indian coals. A regional scale underground coal seam/block was modelled using a commercial reservoir simulator, COMET3. It was found that approximately 218 Mm^3 of CO_2 can be sequestered in place of 74 Mm^3 of CH_4 produced from the chosen dimensions of coal block. The changes in fracture gas saturation, matrix CO_2 concentration and matrix CH_4 concentration with space and time were monitored. Eventually, the numerical values for peak saturation at certain time intervals have been reported. This study is an initial technical estimate for CO_2 driven enhanced CBM at a regional scale in India. The results are expected to prove useful not only to reduce India's contribution to greenhouse gases emission into the atmosphere but also to partially meet with the growing energy demand by enhanced recovery of methane from deep, unminable coal seams.

13/01932 Sources and vertical distribution of ^{137}Cs, ^{238}Pu, $^{239+240}$Pu and ^{241}Am in peat profiles from southwest Spitsbergen

Łokas, E. *et al. Applied Geochemistry*, 2013, 28, 100–108.

This paper presents a detailed survey of the activities of selected man-made radionuclides in peat deposits located in south-west Spitsbergen. Peat cores from the High Arctic (south-west Spitsbergen) were analysed by gamma spectrometry (^{137}Cs), alpha spectrometry (^{238}Pu, ^{239,240}Pu, ^{241}Am activities) and by ICPMS (^{240}Pu/^{239}Pu atom ratios). Maximum activities evident in the peats correspond to the 1963/1964 global maximum fallout from atmospheric testing of nuclear weapons; some of the activity profiles have been altered post-deposition by water infiltration. Activity ratios of ^{238}Pu/$^{239+240}$Pu, ^{241}Am/$^{239+240}$Pu, $^{239+240}$Pu/^{137}Cs and ^{240}Pu/^{239}Pu atom ratios indicate mixing between global (stratospheric) and regional (tropospheric) sources of these radionuclides in the Svalbard area. The ^{238}Pu/$^{239+240}$Pu activity ratios varied from 0.02 ± 0.01 to 0.09 ± 0.03, suggesting global fallout as the dominant source of Pu. The $^{239+240}$Pu/^{137}Cs activity ratios varied from 0.01 ± 0.01 to 0.42 ± 0.11, which apparently arises from the post-depositional mobility of ^{137}Cs. The ^{241}Am/$^{239+240}$Pu activity ratios ranged between 0.10 ± 0.02 and 1.5 ± 0.3 and exceed the published global fallout ratio for Svalbard of 0.37 due to the relatively higher geochemical mobility of Pu vs Am and/or ingrowth of Am from the decay of ^{241}Pu. The atom ratio ^{240}Pu/^{239}Pu ranged from 0.142 ± 0.006 to 0.241 ± 0.027; however, the vast majority of peat samples exhibited ^{240}Pu/^{239}Pu atom ratios similar to the stratospheric fallout (~0.18).

Preparation

13/01933 Effects of chromium ion on sulfur removal during pyrolysis and hydropyrolysis of coal

Huang, J. *et al. Journal of Analytical and Applied Pyrolysis*, 2012, 97, 143–148.

The effects of impregnated Cr^{3+} on sulfur removal during pyrolysis and hydropyrolysis of coal were investigated by loading $CrCl_3$ into raw, demineralized and pyrite removed coal, respectively. The results indicate that Cr has no effect on the removal of pyrite. Cr affects the removal of total sulfur by forming Cr_7S_8 and affecting the removal of organic sulfur. Cr acts as the sulfur removing agent by promoting the decomposition of the unstable organic sulfur at low temperature. However, it behaves to be sulfur fixing agent between 400 and 700 °C so as to inhibit the evolution of H_2S, even in hydropyrolysis. With the increase of temperature from 700 to 1050 °C, a certain ratio of Cr_7S_8 is converted into organic sulfur during pyrolysis; however, almost all the Cr_7S_8 is reduced into Cr at 1050 °C during hydropyrolysis. And Cr significantly promotes the removal of organic sulfur at high temperature within reducing atmosphere. The XPS results indicate that the sulfur is enriched on coke surface by Cr, which is attributable to the formation of Cr_7S_8 as well as the transfer of organic sulfur from bulk to surface during pyrolysis and hydropyrolysis.

13/01934 Experimental investigations on the performance of a new design of foaming agent adding device used for dust control in underground coal mines

Wang, H. *et al. Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 1075–1084.

In order to overcome the drawbacks of foam technology for controlling mine dust, an original design of foaming agent adding device was introduced, and its performance was investigated experimentally under different working flows and outlet pressures, and compared to the conventional jet adding device. The results show that the new design of the foaming agent adding device has a reasonable cavity negative pressure, does not produce cavitations, and has a lower inlet pressure demand with less pressure loss. Furthermore, it can add foaming agent at 0.5–1.0% and regulate the proportions at this low ratio range continuously and stably, which significantly reduces the cost of controlling dust with foam. In addition, it decreases electric energy consumption and simplifies the foam system with no need for extra boosters. Besides, its effect on suppressing mine dust was investigated in the field via dust sample collections, and the results show that this new device is as effective at dust suppression as the conventional one. Therefore, it is believed that this study laid an important foundation for the widespread application of foam technology for dust control in underground coal mines.

13/01935 Mechanisms and kinetic modelling of steam gasification of brown coal in the presence of volatile–char interactions

Kajitani, S. *et al. Fuel*, 2013, 103, 7–13.

It is known that Victorian brown coal has higher reactivity for gasification because of catalysis of inherent AAEM species than high-rank coal. However, the experimental results of steam gasification of brown coal in a fluidized-bed/fixed-bed reactor at 800 °C have suggested that the inhibitory effects of the volatile–char interactions on char gasification are not negligible. The mechanisms and kinetics model of the char gasification and volatile–char interactions were discussed to describe quantitatively the inhibition of char gasification by volatiles, in this study. The elementary reactions of the char gasification and volatile–char interactions, which are consist of the adsorption of free radicals from volatiles, the volatilization of catalyst and the evolution of char structure affected by radicals from volatiles, were proposed. The L–H-type reaction rate equations for brown coal gasification were determined, and the kinetics model was verified by the comparison with several series of experiments. The proposed kinetics model described the experimental results of the coal conversions and the concentrations of Na in char during steam gasification very well. This kinetics model would be useful in designing any industrial fluidized-bed gasifier for low-rank fuels and estimating their performance.

13/01936 Mercury separation from fuel constituents in an ash-free coal manufacturing process

Yoshiie, R. *et al. Fuel*, 2012, 102, 26–31.

A novel process to produce ash-free coal, called hyper-coal (HPC), has been developed based on the coal liquefaction with organic solvent extraction. Via the dissolution in 1-methylnaphthalen at 633 K, 70 wt% of combustible contents can be extracted from raw coal, reducing the ash and alkali contents to less than 1000 and 0.5 ppm, respectively. This process is also a promising approach to separate toxic trace elements from fuel constituent in coal before its combustion. Mercury is one of the toxic trace elements of growing concern, because mercury emission from a coal combustion process to the atmosphere has been becoming a serious problem in the coal use all over the world. Therefore, in this study, various intermediate products such as coal–organic solvent slurry were sampled from the HPC manufacturing process, and analysed for mercury contents to investigate the mass balance and the distribution behaviour of mercury in the process. As a result, it was found that a large portion of the mercury was separated from fuel constituents and recovered as a dissolved matter in the solvent. This dissolved mercury, however, built up in the total distribution behaviour of mercury in the HPC manufacturing process again because the solvent was recycled for the coal extraction process without any clean-up treatment this time. Nevertheless, the mercury distributed into the HPC was lowered to be 20% or less of the total found in raw coal.

13/01937 Mixed bacterial consortium as an emerging tool to remove hazardous trace metals from coal

Singh, P. K. *et al. Fuel*, 2012, 102, 227–230.

This paper presents the results of experimental work on the possibility of removal of environmentally sensitive trace elements from coal through treatment with mixed bacterial consortium. In the coals of Kalimantan area, Indonesia the metals like Cd, Cu, Cr, Ni, Pb and Zn have been found to occur in concentrations of 1.96, 59.34, 26.98, 102.68, 14.4 and 172.54 ppm, respectively. The concentrations of these elements are higher when compared with Clarke values in bituminous coals. Mixed bacterial consortium has been used to explore the possibility of removal of these toxic trace elements. The result reveals that the bacterial consortium is efficient to remove more than 80% of metals like Ni, Zn, Cd, Cu and Cr while the removal of Pb is nearly 45%. The removal is seen in the order: Zn > Ni > Cd > Cu > Cr > Pb.

Transport, storage

13/01938 A spatial analysis of China's coal flow

Mou, D. and Li, Z. *Energy Policy*, 2012, 48, 358–368.

China's coal demand grows at almost the same pace as China's GDP. Because of the regional discordance between coal supply and demand, coal transportation has become the bottleneck of China's economic growth. If this transportation cannot be arranged efficiently, China will face a more serious energy crisis than those faced by Western countries in the 1970s. As traditional coal supplying provinces' production levels reach their Hubbert Peaks and more coal resources are found in north and northwest China, especially Neimeng and Xinjiang, the coal-supplying centre is slowly shifting. Xinjiang is located too far away to supply coal directly to the east at present, but in the mid-long run, it will become a primary coal-supplying province because of China's huge coal demand base and its high growth rate. China must enhance its coal transportation infrastructure. According to the results of this paper, to guaranty mid-long run coal supply security, China should take measures on several fronts. First, China must build up infrastructure to enhance the coal loading capacity in Bohai Bay. As coal demands in eastern and south-eastern China increase, the coal transported by Bohai Bay will also increase. Second, China must strengthen Shandong province's back-up coal transportation status. When the Daqin Railway is capacity constrained, coal out of Shanxi can be transported to Shandong and loaded on to ships there. Third, China must focus on the construction of railway arteries for the transportation of coal. Rail is the primary coal transportation method on land. Because the north-south railways are fully occupied, even the construction of high-speed railways will provide little capacity for coal transportation on that route. It is necessary to exploit and build new west–east railways for coal transportation. Finally, China must exploit the Yangtze River's coal transportation capacity to lower China's coal transportation costs and to alleviate railway pressure. This demands the construction of new railways and ports. If the Hanjiang River's coal transportation potential could be fully utilized, China would have an inexpensive water route to transport coal from the northwest to the lower-middle reaches of the Yangtze River. A railway coal artery is still necessary because it is more capable and reliable. The authors conclude that coal exploitation and transportation will benefit not only eastern China but also central and western China, providing greater stimulus for China's West Development and Rise of Central China projects.

Economics, business, marketing, policy

13/01939 A NaY zeolite synthesized from Colombian industrial coal by-products: potential catalytic applications

Ríos R., C. A. *et al. Catalysis Today*, 2012, 190, (1), 61–67.

The synthesis of the NaY zeolite framework has been performed from Colombian industrial coal by-products by alkaline fusion step prior to hydrothermal reaction. The as-synthesized zeotype was characterized by Fourier transformed infrared (FTIR) spectroscopy, scanning electron microscopy (SEM) and X-ray powder diffraction (XRPD) analysis. Results show that the NaY zeolite can be prepared under the following optimized experimental conditions: at 80 °C for 12 h from natural clinker and at 65 °C for 96 h from fly ash, although the conversion of fly ash was not very effective compared with that obtained using natural clinker. Ion exchange of metal ions in NaY zeolite is suggested to investigate its catalytic activities and its ion exchanged forms.

13/01940 A supply chain based assessment of water issues in the coal industry in China

Pan, L. *et al. Energy Policy*, 2012, 48, 93–102.

Shortages of water and geographically uneven distribution of coal and water pose great challenges to sustainable development of the coal industry in China. This study illustrates the major challenges existing in the coal industry from a supply chain viewpoint, and propose technical and policy suggestions to address them. First, the authors provide quantitative information about water withdrawal, consumption, wastewater recycling and treatment and pollution from coal mining, preparation, to final conversion for China's power generation and coal-to-chemical industry. The authors then analyse scenarios of water use in China's coal industry between 2020 and 2030. The results show that water issues are becoming increasingly severe constraints for coal development in China, especially in North and West China, where water is more scarce and ecological systems are more vulnerable than other regions. Without implementing effective water-saving measures or regulations the water demand in the coal industry could dramatically increase and probably exceed China's water supply capacity in the near-term future, bringing substantial uncertainty to sustainable development of China's energy economy. The authors also illustrate that coal-fired power generation, with appropriate technical improvement and proper policy supports, has the greatest potential for water savings in the coal industry. The conclusions also underscore the importance of expanding energy efficiency and renewable energy in China so as to limit the country's dependence on coal.

13/01941 An investigation of the role of China's urban population on coal consumption

Michieka, N. M. and Fletcher, J. J. *Energy Policy*, 2012, 48, 668–676.

This paper investigates the causal relationship between urban population, real GDP, electricity production and coal consumption in China for the period 1971–2009. Using a vector autoregression framework and a modified version of the 1969 Granger causality test proposed by Toda and Yamamoto in an earlier study, the results suggest that there is causality running from gross domestic product (GDP) to coal consumption. The variance decomposition analysis reported that urban population and coal affect electricity production variability over the forecast period. It was also found that increasing urban population may negatively affect China's GDP over time. Policy measures aimed at influencing GDP could ultimately affect coal consumption.

13/01942 Causality-in-mean and causality-in-variance within the international steam coal market

Papież, M. and Śmiech, S. *Energy Economics*, 2013, 36, 594–604.

The purpose of this paper is to investigate the integration of the steam coal market. The analysis of dependencies between mean rates of return of prices on the steam coal market and volatility spill-over was conducted using weekly data from 4 January 2002 to 30 December 2011. The prices of the world's largest exporters and importers on the Pacific and Atlantic markets were chosen to analyse the dependencies. The methodology was based on the tests from earlier studies that allow for the analysis of Granger causality both in mean and in variance. The analyses indicate that the dependence between participants is not the same. The strongest links were observed between the pairs of participants from the same market (that is, either the Atlantic market or the Pacific market), and the price of Australian coal turned out to be the most important factor in shaping other prices on the Pacific market. On the Atlantic market, the coal prices in the Amsterdam–Rotterdam–Antwerp ports and the Richards Bay port had the greatest influence on coal prices and were the Granger cause of prices in the Pacific region.

13/01943 Coal fires, fresh air and the hardy British: a historical view of domestic energy efficiency and thermal comfort in Britain

Rudge, J. *Energy Policy*, 2012, 49, 6–11.

Fuel poverty has been most commonly researched in the UK although it is experienced in other parts of Europe, to varying degrees. Studies have shown that energy inefficient buildings and heating systems are the most significant components of fuel poverty and highlighted the legacy of older buildings in this country that remain the majority of those now recognized as hard to treat. This paper considers the historical context for fuel poverty as a particularly British phenomenon. It examines claims that this is due to the mild climate and low indoor temperature expectations. It is concluded that there are significant differences from the European situation. The climate, particularly its characteristic changeability, has influenced building and heating methods, and the low priority given to energy efficiency by legislators. Significantly, economic priorities produced poor quality mass housing during the industrial revolution. The availability of coal encouraged the use of open fires, which demanded high ventilation rates. The British do value warmth but older buildings designed for heating with radiant open fires are difficult to adapt to convective central heating. Lessons can be drawn for newly industrialized economies similarly producing poor quality mass housing with low priorities for energy efficiency.

13/01944 Multi-objective optimization of coal-fired electricity production with CO_2 capture

Cristóbal, J. *et al. Applied Energy*, 2012, 98, 266–272.

The use of oxy-combustion is an attractive alternative to amine based absorption of CO_2 to retrofit coal-fired power plants. The aim of this work is to compare these two carbon capture technologies taking into account environmental and economic criteria. To this end, The authors have developed a rigorous bi-criteria mixed-integer non-linear programming model that allows identifying in a systematic and rigorous manner the best pollution control technologies (including carbon capture devices) to be installed in an existing coal-fired plant. They have applied this methodology to a coal-fired power plant of a given capacity. Numerical results indicate that carbon capture with MEA performs better for soft environmental limits while oxy-fuel combustion is the preferred choice when more stringent environmental limitations are considered.

13/01945 What about coal? Interactions between climate policies and the global steam coal market until 2030

Haftendorn, C. *et al. Energy Policy*, 2012, 48, 274–283.

Because of economic growth and a strong increase in global energy demand the demand for fossil fuels and therefore also greenhouse gas emissions are increasing, although climate policy should lead to the opposite effect. The coal market is of special relevance as coal is available in many countries and often the first choice to meet energy demand. This paper assesses possible interactions between climate policies and the global steam coal market. Possible market adjustments between demand regions through market effects are investigated with a numerical model of the global steam coal market: the 'COALMOD-World' model. This equilibrium model computes future trade flows, infrastructure investments and prices until 2030. The authors investigate three specific designs of climate policy: a unilateral European climate policy, an Indonesian export-limiting policy and a fast-roll out of carbon capture and storage in the broader context of climate policy and market constraints. They find that market adjustment effects in the coal market can have significant positive and negative impacts on the effectiveness of climate policies.

Derived solid fuels

13/01946 Determination of effective thermal conductivity and specific heat capacity of wood pellets

Guo, W. *et al. Fuel*, 2013, 103, 347–355.

Effective thermal conductivity and specific heat capacity are important properties for studying the self-heating during wood pellets storage. A modified line heat source within a wood pellets container was used to determine the thermal conductivity and specific heat capacity of wood pellets with moisture content ranging from 1.4% to 9% w.b. A second-order partial differential equation describing transient temperature distribution within the test container was numerically solved for temporal and spatial temperatures. The difference between experimental and numerical temperatures was minimized to estimate an effective thermal conductivity and specific heat capacity for the bulk pellets. The estimated thermal conductivity ranged from 0.146 to 0.192 W/(m K) increasing with moisture content. An empirical relationship among effective thermal conductivity, moisture content and porosity was developed. The dependence of effective thermal conductivity on pellets size was negligible. The estimated specific heat capacity of pellets ranged from 1.074 to 1.253 kJ/(kg K) in the tested range. A relation between specific heat capacity and moisture content was developed for general wood pellets.

13/01947 Effects of pyrolysis temperature on soybean stover- and peanut shell-derived biochar properties and TCE adsorption in water

Ahmad, M. *et al. Bioresource Technology*, 2012, 118, 536–544.

Conversion of crop residues into biochars (BCs) via pyrolysis is beneficial to environment compared to their direct combustion in agricultural field. Biochars developed from soybean stover at 300 and 700 °C (S-BC300 and S-BC700, respectively) and peanut shells at 300 and 700 °C (P-BC300 and P-BC700, respectively) were used for the removal of trichloroethylene (TCE) from water. Batch adsorption experiments showed that the TCE adsorption was strongly dependent on the BCs properties. Linear relationships were obtained between sorption parameters (K_M and S_M) and molar elemental ratios as well as surface area of the BCs. The high adsorption capacity of BCs produced at 700 °C was attributed to their high aromaticity and low polarity. The efficacy of S-BC700 and P-BC700 for removing TCE from water was comparable to that of activated carbon (AC). Pyrolysis temperature influencing the BC properties was a critical factor to assess the removal efficiency of TCE from water.

13/01948 Gasification of char from wood pellets and from wood chips: textural properties and thermochemical conversion along a continuous fixed bed

Teixeira, G. *et al. Fuel*, 2012, 102, 514–524.

In fixed bed gasifiers, the char bed gasification zone where char is converted into syngas plays a major role in terms of efficiency and control of the process. This zone is particularly complex as many phenomena compete, i.e. heterogeneous and homogeneous chemical reactions, gas flow in porous medium and flow of solid particles. This paper investigates the mechanical and thermochemical behaviour of the char bed gasification zone and focuses particularly on bed compaction. To achieve this, a low-density biomass char from wood chips and a high-density one from wood pellets were gasified in a pilot scale continuous fixed bed reactor. Measurements of profiles were taken along the char bed for temperature, gas species concentration, char composition, char bed density and char particle velocity using fine instrumentation and specific char and gas sampling techniques. In these operating conditions, the char bed reactive zone is three times longer for chips (45 cm) than for pellets (16 cm). It was shown that pelletization has no effect on: char bed compaction, final char conversion (about 95%) and syngas quality (16% H_2 and 13% CO). Finally, the authors discuss char bed compaction and the main phenomena that control it in order to propose a line of enquiry for modelling.

13/01949 Influence of the inherent metal species on the graphitization of methane-based carbon nanofibers

Cameán, I. *et al. Carbon*, 2012, 50, (15), 5387–5394.

Carbon nanofibres (CNFs) containing different proportions of Ni and Si were produced from methane decomposition in a fluidized bed reactor with a nickel–copper-based catalyst. They were subjected to heat treatment in the temperature interval 1800–2800 °C for the purpose of studying the influence of the inherent metal species on their ability to graphitize. The participation of Ni and Si species on the graphitization of the methane-based CNFs through the formation of a nickel silicide phase as an intermediate state which further promotes the production of silicon carbide was inferred. Moreover, since silicon carbide was observed by X-ray diffraction after the heat treatment of the CNFs at temperatures $\geq$2400 °C, the formation of graphite at the expense of the carbide decomposition seems to be a plausible mechanism to explain the catalytic graphitization of these CNFs. Because of this effect, carbon materials with crystalline parameters in the range of synthetic graphites which are currently employed in energy applications were prepared in this work. A progressive improvement of the degree of the structural order of the materials prepared with increasing Si/Ni weight ratio in the CNFs was observed.

13/01950 Microcosm study on the decomposability of hydrochars in a Cambisol

Gajić, A. *et al. Biomass and Bioenergy*, 2012, 47, 250–259.

The process of hydrothermal carbonization (HTC) converts biomass into a carbonaceous product named hydrochar. It is hypothesized that due to a high recalcitrance against microbial decomposition in soil, hydrochar may contribute to carbon (C) sequestration, thereby sustaining its function as a soil conditioner. The objective of this microcosm study was to identify process parameters of hydrochar production affecting the stability of hydrochar-C against decomposition, and thus its C sequestration potential. A variety of hydrochars differing in processing temperature (180–250 °C) and time (4–12 h), and feedstock material (sugarbeet pulp, draff) as well as reference materials [wheat straw (WS), mature compost (MC), white peat (WP), sugarbeet pulp biochar (SB)] were applied to soil in a concentration equivalent to 30 t ha^{-1} incorporated into 15 cm soil depth. After 248 days of incubation, C mineralized from the hydrochars ranged from 12 to 32%; it decreased considerably with increasing processing temperature from 200 to 250 °C, and less pronounced with increasing processing time from 4 to 12 h, whereas feedstock had no distinct effect. Higher processing temperature reduced oxygen content in hydrochar thus decreasing its reactivity, which resulted in both a higher amount and mean residence time of the stable hydrochar-C fraction. The mean residence times of tested organic materials followed the order: WS $\ll$ hydrochars < WP <<< SB, MC. Thus, the application of hydrochar as a soil conditioner under field conditions may offer a moderate potential for C sequestration. A comprehensive evaluation of the complete HTC process chain including C and energy balances is prospectively required.

13/01951 Pulses of microwave radiation to improve coke grindability

Ruisánchez, E. *et al. Fuel*, 2012, 102, 65–71.

Metallurgical cokes are made by destructive distillation of bituminous coals and they have a high content in elemental carbon; however, the inorganic elements that were part of the original bituminous coal remain trapped in the resultant coke, having very different capacities for absorbing microwave radiation. Therefore, when cokes are irradiated with microwaves, some parts of the particle will undergo rapid heating, while others parts will heat up slowly. Moreover, due to the electrical conductivity exhibited by metallurgical cokes, microwave radiation gives rise to electric arcs or microplasmas, producing hot spots. As a result of the expansion and the stresses caused by thermal shock, small cracks and micro-fissures appear on the surfaces, leading to a weakening of the coke particles and facilitating their grindability. This paper studies, at laboratory scale, the microwave-assisted grinding of metallurgical coke and assesses the improvement in grindability and the amount of energy saved. It was found that treatment consisting of short pulses of microwave irradiation produces better results than the continuous heating used in previous studies.

13/01952 Radial voidage variation in fixed beds of fuel wood pellets

Hamel, S. and Krumm, W. *Biomass and Bioenergy*, 2012, 46, 203–209.

Fixed beds of fuel wood are commonly found in numerous processes: storage and transportation, drying and thermal conversion such as combustion or gasification. Pellets in particular are mostly used as fuel for domestic heating boilers. The characterization of spatial voidage distribution is of great importance for flow and reactor modelling. The present study focuses on the radial porosity variations of cylindrical beds of commercially available wood pellets. The experimental procedure is based on the classical technique of consolidating packed beds with a resin. The radial voidage distribution of three different cylindrical beds is determined by image analysis of sections of the solidified packing. The results are discussed and summarized in a mathematical expression correlating the radial voidage distribution depending on packing core porosity and dimensionless distance from the tube wall.

02 LIQUID FUELS

Sources, properties, recovery

13/01953 Application of biological markers in the recognition of the geochemical characteristics of some crude oils from Abu Gharadig Basin, north Western Desert – Egypt

El Diasty, W. S. and Moldowan, J. M. *Marine and Petroleum Geology*, 2012, 35, (1), 28–40.

The objective of this study is to establish the relationship between the hydrocarbons recovered from the Abu Gharadig Basin and Middle Jurassic Khatatba Formation, as well as the previously established Upper Cretaceous Abu Roash-F Member. A suite of 14 crude oil and condensate samples from the Mesozoic reservoirs (Jurassic–Cretaceous) of the Abu Gharadig Basin (Western Desert, Egypt) was analysed and geochemically compared with extracts from source rocks of the Middle Jurassic (Khatatba Formation) and the Upper Cretaceous (Abu Roash–F Member). Based on molecular indicators of organic source input, depositional environment and age-diagnostic biomarkers, at least two petroleum systems operate in the Abu Gharadig Basin; those derived from Late Cretaceous marine shales and Jurassic–Early Cretaceous non-marine organic-rich shales as source rocks and possibly a third system appears to be a mixture of them both. The correlation of some Abu Gharadig oils to a Late Cretaceous source establishes a petroleum system involving these marine Cretaceous source rocks.

13/01954 Dynamic interfacial tension behaviors between Guerbet betaine surfactants solution and Daqing crude oil

Qiao, W. *et al. Fuel*, 2012, 102, 746–750.

In the surfactant flooding systems for enhanced oil recovery, interfacial tension between surfactant solution and crude oil should be decreased to ultralow value ($<10^{-2}\,\mathrm{mN\,m^{-1}}$). Accordingly, in this paper, the dynamic interfacial tension behaviours between Guerbet betaine surfactants solution and Daqing crude oil were studied. The influence factors such as ethylene oxide groups, surfactant concentration, and the mass ratio of compound systems, sodium carbonate concentration and temperature were investigated. It was found that the prepared surfactants used alone cannot reduce the dynamic interfacial tension to ultralow value. In order to meet the demand, the compound systems were taken into account. The results showed that the effect of GC16 (3)/GC20 (5) compound system was better than GC16 (3)/GC18 (5) and GC20 (5)/GC18 (5). When the mass ratio of GC16 (3)/GC20 (5) was 9:1, the dynamic interfacial tension can reach ultralow value. Then the effect of sodium carbonate concentration and temperature were studied for this better compound system (GC16 (3)/GC20 (5) = 9:1), the results showed that this compound system existed an optimum sodium carbonate concentration and exhibited good temperature resistance.

13/01955 Effective characterization of petroleum C_{7+} fractions

Eckert, E. *et al. Fuel*, 2012, 102, 545–553.

Petroleum fractions are typical complex mixtures. For the simulation of petroleum refining processes they are characterized by substitute mixtures. In this contribution the traditional approach based on pseudocomponents is compared with the newer approach utilizing a substitute mixtures of real components (SMRCs). The main advantage of SMRC approach is the direct availability of physical property data and the knowledge of the chemical character. The most important task in many applications is to characterize the C_{7+} fraction. It is shown, how it can be characterized by a small number of real components. The examples used for comparison comprise separation processes and also the pyrolysis modelling, where the known chemical character of a SMRC is crucial for feeding an artificial neural network model.

13/01956 Estimation of crude oil salt content using a simple predictive tool approach

Bahadori, A. *et al. Journal of Petroleum Science and Engineering*, 2012, 96–97, 68–72.

The removal of salt from crude oil for oil-field processing has been and still is a mandatory requirement. Salt in crude oil is, in most cases, found dissolved in the remnant brine within the oil. The chemical composition of these salts varies, but the major portion is nearly always sodium chloride. This remnant water exists in the crude oil as a dispersion of very fine droplets highly emulsified in the bulk of oil. In this work, a simple predictive tool for practical correlation for salt content in crude oil as a function of brine quantity that remains in the oil, its salinity (in vol% of sodium chloride concentration) and temperature using an exponential function has been formulated. The proposed method predicts the amount of salt in the crude oil for temperatures up to 373 K and sodium chloride concentrations up to 250,000 ppm (25% by volume). Estimations from the proposed correlation are found to be in excellent agreement with the reported data in the literature with average absolute deviation being 0.3%. The tool developed in this study can be of immense practical value for the engineers to have a quick check on the salt content in the crude oil at various conditions without opting for any experimental measurements. In particular, petroleum and field engineers would find the approach to be user-friendly with transparent calculations involving no complex expressions.

13/01957 Gas hydrate formation and its accumulation potential in Mohe permafrost, China

Zhao, X. *et al. Marine and Petroleum Geology*, 2012, 35, (1), 166–175.

The Mohe region is an area of continuous permafrost in northernmost China with strong similarities to other known gas-hydrate-bearing regions. Permafrost thickness is typically 20–80 m; average surface temperature ranges from –0.5 to –3.0 °C, and the geothermal gradient is roughly 1.6 °C/100 m. The authorsestimate that $204.66 \times 10^{12}\,\mathrm{m}^3$ of hydrocarbon gases have been generated in the Mohe basin from nearly 1000 m middle Jurassic dark mudstones, providing ample gas source for gas hydrate formation. Numerous folds in the shallow section provide opportunities to trap gas within sandstones and siltstones reservoirs bounded by competent mudstone seals. Gas migration to the shallow section is enabled via fault fracture zones and fracture systems. Based on core description and observations of gas releases from drilled wells, the Mohe region could hold large quantities of natural gas in the form of gas hydrate.

13/01958 New predictive tools to estimate diesel oil density and viscosity

Ghaderi, A. *Journal of Petroleum Science and Engineering*, 2012, 98–99, 19–21.

Density and viscosity of diesel oils are vital parameters in determination of density and viscosity of oil-based muds. The purpose of current study is to develop new simple, reliable and explicit predictive tools to estimate diesel oil density and viscosity through multiple regression analysis. These methods are applicable from atmospheric pressure to 15,000 psia and temperature up to 350 °F. Results are found to be in good agreement with data with average absolute error being around 0.968% and 2.717%, for density and viscosity, respectively.

13/01959 Reactivity of dolomite in water-saturated supercritical carbon dioxide: significance for carbon capture and storage and for enhanced oil and gas recovery

Wang, X. *et al. Energy Conversion and Management*, 2013, 65, 564–573.

Carbon dioxide injection in porous reservoirs is the basis for carbon capture and storage, enhanced oil and gas recovery. Injected carbon dioxide is stored at multiple scales in porous media, from the pore-level as a residual phase to large scales as macroscopic accumulations by the injection site, under the caprock and at reservoir internal capillary pressure barriers. These carbon dioxide saturation zones create regions across which the full spectrum of mutual CO_2–H_2O solubility may occur. Most studies assume that geochemical reaction is restricted to rocks and carbon dioxide-saturated formation waters, but this paradigm ignores injection of anhydrous carbon dioxide against brine and water-alternating-gas flooding for enhanced oil recovery. A series of laboratory experiments was performed to evaluate the reactivity of the common reservoir mineral dolomite with water-saturated supercritical carbon dioxide. Experiments were conducted at reservoir conditions (55 and 110 °C, 25 MPa) and elevated temperature (220 °C, 25 MPa) for approximately 96 and 164 h (4 and 7 days). Dolomite dissolves and new carbonate mineral precipitates by reaction with water-saturated supercritical carbon dioxide. Dolomite does not react with anhydrous supercritical carbon dioxide. Temperature and reaction time control the composition, morphology, and extent of formation of new carbonate minerals. Mineral dissolution and re-precipitation due to reaction with water-saturated carbon dioxide may affect the contact line between phases, the carbon dioxide contact angle, and the relative permeability and permeability distribution of the reservoir. These changes influence fundamental properties of hysteresis of drainage and imbibition cycles, rock wettability, and capillary pressure. The efficacy of physical carbon dioxide trapping mechanisms, integrity of caprock, and injectivity of a carbon dioxide storage reservoir as well as the injectivity and production rate of an enhanced oil recovery operation may be affected.

13/01960 Simultaneous determination of ethanol and methanol in fuel ethanol using cyclic voltammetry

Pereira, P. F. *et al. Fuel*, 2013, 103, 725–729.

A new and simple strategy for the simultaneous determination of ethanol and methanol in fuel ethanol using cyclic voltammetry at a gold electrode is reported. A fuel ethanol aliquot was added into an electrochemical cell containing $0.5\,\mathrm{mol\,L^{-1}}$ NaOH and 0.1% (v/v) of methanol as the electrolyte and both analytes were determined using cyclic voltammetry. Ethanol was selectively detected at +0.19 V and both compounds were detected at +1.20 V. Current subtraction (using a correction factor) could be used for the selective determination of methanol. The limits of detection were estimated to be 0.028% and 0.045% (v/v) for ethanol and methanol, respectively. The proposed method presented similar results to those obtained by gas chromatography at a 95% confidence level.

13/01961 The use of thermal lens spectroscopy to assess oil–biodiesel blends

Ventura, M. *et al. Fuel*, 2013, 103, 506–511.

Thermal lens (TL) spectroscopy in a dual-beam configuration was applied in a study on biodiesel and oil–biodiesel blends. The goal of this work was to evaluate the behaviour of the thermal and mass diffusivities that arose when oil was added to biodiesel and to verify the capability of the method to identify small concentrations of triacylglycerol in biofuel. When transitioning from pure biodiesel to a blend consisting of 98% biodiesel and 2% soybean oil, the thermal diffusivity decreased 15% and the mass diffusivity increased 59%, which indicated that both parameters can provide significant information about the presence of oil in biodiesel. Therefore, TL spectroscopy can be a useful method for certifying the quality of biodiesel and biodiesel blends.

Transport, refining, quality, storage

13/01962 A state space model for transient flow simulation in natural gas pipelines

Alamian, R. *et al. Journal of Natural Gas Science and Engineering*, 2012, 9, 51–59.

A transient flow simulation for gas pipelines and networks is proposed. The proposed transient flow simulation is based on the state space equations. These equations are derived by the transfer function equations. However, the transfer function model cannot be used for a complicated network. One can easily apply a state space model for a large and complicated network. For a state space model, the equivalent transfer functions of the non-linear governing equations are derived for different boundary condition types. Next, the state space equations are derived from the transfer functions. To verify the accuracy of the proposed simulation, the results obtained are compared with those of the conventional finite difference schemes (such as total variation diminishing algorithms, method of lines, and other finite difference implicit and explicit schemes). The effect of the flow inertia is incorporated in this simulation. The accuracy and computational efficiency of the proposed method are discussed for a single gas pipeline and a sample gas network; besides for accuracy of this method for different boundary conditions, results for a sample gas pipeline with different boundary conditions are compared.

13/01963 Application of the self-heat recuperation technology to crude oil distillation

Kansha, Y. *et al. Applied Thermal Engineering*, 2012, 43, 153–157.

Crude oil distillation is an atmospheric distillation column using a furnace. It consumes about 50% of the energy required in an oil refinery plant. To reduce energy requirements, it is necessary to investigate crude oil distillation and to retrofit it with energy saving processes. Recently, the authors developed an innovative process design technology, termed self-heat recuperation technology for saving energy. To apply this technology, whole-process heat is recirculated within the process without heat addition, leading to large energy savings. In this paper, crude oil distillation is analysed and a crude oil distillation model for an energy saving design is developed. Furthermore, the feasibility of application of self-heat recuperation technology is investigated and self-heat recuperative crude oil distillation is proposed.

13/01964 CFD modeling of fouling in crude oil pre-heaters

Bayat, M. *et al. Energy Conversion and Management*, 2012, 64, 344–350.

In this study, a conceptual procedure based on the computational fluid dynamic (CFD) technique has been developed to predict fouling rate in an industrial crude oil pre-heater. According to the developed CFD concept crude oil was assumed to be composed of three pseudo-components comprising of petroleum, asphaltene and salt. The binary diffusion coefficients were appropriately categorized into five different groups. The species transport model was applied to simulate the mixing and transport of chemical species. The possibility of adherence of reaction products to the wall was taken into account by applying a high viscosity for the products in competition with the shear stress on the wall. Results showed a reasonable agreement between the model predictions and the plant data. The CFD model could be applied to new operating conditions to investigate the details of the crude oil fouling in the industrial pre-heaters.

13/01965 Demulsifying super-heavy crude oil with bifunctionalized block copolymers

Cendejas, G. *et al. Fuel*, 2013, 103, 356–363.

One of the main problems that petroleum industry must face is the growing difficulty to extract both water and salts present in heavy crude oils. High viscosity, and enormous contents of resins and asphaltenes contribute to stabilize the water droplets dispersed in crude oil, making petroleum demulsification harder and the development of new dehydrating agents necessary. A series of copolymers consisting on a central block polypropylene oxide (PPO), and two side block of ethylene oxide (EO) were synthesized. These copolymers were afterwards submitted to a functionalization process, in order to graft some secondary amines to EO segments, to increase their interactions with the aqueous phase dispersed in the petroleum. The average molecular weight of the functionalized copolymers was adjusted according to the weight-average molecular weight (M_w) of the sample of super-heavy crude oil. The water removals from the petroleum sample were evaluated by bottle testing, mainly varying the kind of functional group and copolymer content. It was observed that these novel demulsifying agents have a better performance than traditional compounds, such as non-functionalized block copolymers and commercial formulations commonly used to remove water from super-heavy crude oil. The existence of maximal water separation at a certain concentration of the functionalized copolymers was observed, and explained in terms of a saturation of the water/oil interphase with polymeric chains.

13/01966 Effect of polar/nonpolar groups in comb-type copolymers on cold flowability and paraffin crystallization of waxy oils

Xu, J. *et al. Fuel*, 2013, 103, 600–605.

Comb-type poly(maleic alkylamide-co-α-octadecene) copolymers (MACs) with various ratios of polar carboxyl group/non-polar octadecyl group were synthesized. On cooling, MACs change the size and shape of paraffin crystals, and reduce the pour point and yield stress of waxy oils, as observed by rheology, polarizing light microscopy, differential scanning calorimetry, and X-ray diffraction. They also reduce the paraffin crystallization temperature and enthalpies, inhibit the formation of layer structure of paraffin crystals. Their efficiency to improve the cold flowability was found to correlate to the ratio of polar/nonpolar group (r). MAC with r of 0.4, is more effective than the other two in improving the flowability of waxy oils. It seems that MAC2 can balance the competitive assembly behaviours of copolymers with paraffins and asphaltenes. The assembly between the carboxyl and amide groups of MACs with polar aromatic asphaltenes appears to stabilize crude oil by the steric effects of the long-chain alkyl branches of MAC polymers, thereby improving the flowability of paraffin/asphaltene gels formed on cooling.

13/01967 Experimental analysis of the evaporation process for gasoline

Zhu, L. *et al. Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 916–922.

This paper presents the findings from a study on the evaporation process of 93 RON (research octane number) unleaded gasoline. The parameters measured in the experiment included the weight, the RVP (Reid vapour pressure) and the viscosity of gasoline, the concentration of NMHC (non-methane total hydrocarbon) in the oil vapour and the concentration of the main vapour constituent. Results showed that the parameters changed significantly as evaporation processed. The weight loss reached 86.36% after 300 days and presented a logarithmic curve with time. The RVP decreased from 38 to 9.6 kPa. The viscosity of gasoline increased from 8.6×10^{-4} to 1.51×10^{-3} Pa s. All the concentrations of NMHC and the main constituent of vapour decreased in varying amounts. Most of the changes might be attributed to the evaporation of volatile hydrocarbons.

13/01968 Experimental investigation on simultaneous charging and discharging of an oil storage tank

Mawire, A. *et al. Energy Conversion and Management*, 2013, 65, 245–254.

An experimental setup for simultaneous charging and discharging experiments to be performed on an oil storage tank is presented. The experimental setup enables thermal energy to be stored in the storage tank as well as water to be heated up for a cooking application in a simultaneous charging and discharge cycle. Results of three different simultaneous charging and discharging cases are presented. The three different cases of simultaneous charging and discharging are; (i) an initially unstratified storage tank, (ii) an initially stratified storage tank, and (iii) an initially unstratified storage tank at the top and stratified at the bottom. The three different cases of simultaneous charging and discharging indicate that water can be boiled within 2 h of the charging/discharging cycle and a sufficient amount of energy can be stored in the storage tank. It is suggested that foods which take longer cooking times can be cooked with the boiling water. The energy stored can be used to heat up or cook foods that require lower cooking temperatures. Thermal stratification in the storage is evident for all of the three cases.

13/01969 Mathematical modeling of thixotropic drilling mud and crude oil flow in wells and pipelines – a review

Livescu, S. *Journal of Petroleum Science and Engineering*, 2012, 98–99, 174–184.

Many drilling muds and crude oils are known to be thixotropic. Under a wide range of pressures, temperatures and flow regimes, they display unusual complex flow properties when flowing through wells (crude oils and drilling muds) and during storage and pipeline transportation (crude oils). Understanding and modelling the deviation from Newtonian behaviour of drilling muds and crude oils are essential in accurately and optimally designing the flow systems associated with these fluids. Despite an impressive amount of experimental and rheological modelling studies concerning the non-Newtonian drilling mud and crude oil behaviour, mathematical modelling studies taking into account their thixotropic properties are rare. In addition, there was no literature review of the knowledge gained to date. Thus, a review paper on studies addressing the mathematical modelling of thixotropic drilling mud and crude oil flow in wells and pipelines will pinpoint the challenges and limitations encountered in such studies. This will hopefully trigger further development and new research topics. This review paper focuses mainly on mathematical modelling studies concerning the well and pipeline flow of thixotropic drilling muds and crude oils. After describing how thixotropy is understood today inside and outside of the petroleum industry community, several mathematical models available in the literature are examined. Finally, challenges, limitations, and potential areas for the development of these models are presented.

13/01970 Prediction of pressure gradient and holdup in wavy stratified liquid–liquid inclined pipe flow

Rodriguez, O. M. H. and Baldani, L. S. *Journal of Petroleum Science and Engineering*, 2012, 96–97, 140–151.

Pressure gradient and holdup data are presented for oil–water flow in a horizontal and inclined 0.026 m i.d. pipe (borosilicate glass, 15.5 m length and pipe inclinations of −10°, −20° and +10°). A wavy stratified flow in the laminar-turbulent regime with no dispersion whatsoever at the interface was observed. The relatively high-viscosity oil flow (280 mPa s) dominates the friction and the low Eötvös number indicates the existence of a wavy and curved interface. A new closure relation for the interfacial friction factor is suggested. Recent interfacial wave amplitude data are used for the proposition of a correlation for the interfacial friction factor based on the equivalent-sand-roughness concept. An explicit equation for the interface shape based on the constant-curvature-arc model is proposed, which is a function of the Eötvös number, holdup and contact angle. A discussion on the typical contact angles observed in liquid–liquid flow in pipes of different materials is carried out. It was found that for the slower lighter phase (oil) the effective wall friction factor is significantly lower than the single-phase friction factor, corresponding to an increase of the respective hydraulic diameter. CFD simulations provided an estimate of the cross-sectional wave shape and delivered holdup and pressure gradient results. The phenomenological model is validated against data from the literature and its predictions are compared with present data, models from the literature and CFD results. The favourable comparisons and simplicity of the proposed closure relations are promising, aiming to practical application.

13/01971 Preparation and characterization of adsorbents for treatment of water associated with oil production

Sueyoshi, M. *et al. Journal of Analytical and Applied Pyrolysis*, 2012, 97, 80–87.

Two sets of adsorbents were prepared from locally available raw materials, characterized and tested. The first set consists of crushed natural attapulgite and crushed attapulgite mixed with petroleum tank-bottom sludge and carbonized at 650 °C. Another set was prepared using trunk of date palm tree (*Phoenix dactylifera*) activated at 700 and 800 °C. Both sets were characterized using BET surface area and pore distributions, FTIR, XRD, SEM and TEM. Natural attapulgite and attapulgite/sludge composite exhibited different characteristics and adsorptive capacities for oil removal from oily water. Adsorptive capacities were calculated from the breakthrough curves of a column test. An oily water solution of about 500 mg-oil/L was passed through both the attapulgite and attapulgite/sludge columns until the column effluent concentration exceeded a reference limit of 10 mg-oil/L. Uptake was calculated at this limit at 155 and 405 mg-oil/g-adsorbent, respectively. This was lower than the performance of a commercial activated carbon sample (uptake calculated at 730 mg-oil/g-adsorbent). Relatively, the date palm, carbonaceous-based adsorbent samples showed less significant differences in both bulk and surface properties. Uptake significantly improved to 1330–1425 mg-oil/g-adsorbent. Attempt was made to associate this performance with the difference in the surface areas between the two sets. However, other factors are found to be important as the second set has a range of surface area less than that of the commercial sample. As evidenced by FTIR, XRD and TEM, the activated carbonaceous materials developed porous structures which form defective graphitic sheet ensembles that serve as additional adsorption sites in the sample.

13/01972 The influence of incorporating a forecutter on the performance of offshore pipeline ploughs

Lauder, K. D. *et al. Applied Ocean Research*, 2013, 39, 121–130.

Installation of offshore pipelines in the seabed can be efficiently achieved using pipeline ploughs. Increased efficiency may be achievable through incorporating a smaller forecutter in advance of the main plough share. Currently guidance is limited and conflicting as to the advantages or disadvantages of incorporating a forecutter. To investigate the effect of forecutter inclusion model tests were undertaken at 1/50th scale under laboratory conditions in sand beds prepared at different relative densities in both dry and saturated conditions. Dry sand tests were used to determine the effect of the forecutter on the static or passive components of plough tow force. The currently adopted passive pressure coefficient (C_s) did not appear to vary with relative density to the same degree as previously suggested and the forecutter increased the magnitude of the passive or static resistance to ploughing. Saturated tests were used to determine the effects of the forecutter on the rate dependant component of ploughing resistance and allow verification of a dimensionless form of rate effect representation. The forecutter acts to reduce the rate effect component of plough tow force in both fine sand (low permeability) and to a lesser extent in medium sand (higher permeability). In fine and silty sands, however, incorporating a forecutter would seem highly beneficial at all ploughing depths and soil densities but in medium sand (higher permeability) the benefits of incorporation are limited to an operating window at shallower trench depths and lower relative density.

13/01973 Water tracers in oilfield applications: guidelines

Serres-Piole, C. *et al. Journal of Petroleum Science and Engineering*, 2012, 98–99, 22–39.

A key parameter in tracing tests is the selection of the molecules used as water tracers. Many previous tests have failed because of improper selection of these molecules. To address this issue, the first part of this paper provides guidelines, offering data and advice for choosing the best possible tracers for a tracing campaign. This part of the paper presents the different types of water tracers proposed and used in oilfield applications, from the first qualitative tracer study in the 1960s to tracer studies in the 2000s, with their respective advantages and drawbacks. The oil industry began to conduct interwell tracer tests with molecules already successfully used in hydrology. These compounds included radioactive species and stable isotopes, chemicals such as fluorescent dyes, and inorganic ions. Some of the early chemical tracers have been rejected because of issues with adsorption onto the rock. Radioactive species, with a low detection limit, a low reactivity, and a low presence in the environment, have been widely used. However, their use has become more restricted throughout the world in response to the radioactive hazards associated with their use. Therefore, new types of non-radioactive tracers were developed and tested in the 1990s. Currently, however, few chemical molecules possess characteristics matching the selection criteria of an effective water tracer (with regard to environmental and economic aspects, etc.). The most effective molecules currently used as water tracers are the fluorinated benzoic acids (FBA); these molecules can be detected with very low limits of detection (LOD) using analytical techniques such as gas chromatography or ultra-high-performance liquid chromatography coupled with mass spectrometers (GC/MS and UHPLC/MS-MS, respectively). The second part of the paper deals with the analytical aspect of a tracing test. An alternative technique to the fluorescence methods currently used for the naphthalene sulfonic acids (NSA) is proposed: UHPLC/MS-MS. With this original tool, FBA and NSA could be simultaneously detected in water samples in only one 5-min analysis. Other molecules, halogenated boronic acids, were also tested analytically for their potential application as tracers. However, these molecules were not retained because of their overly high LOD, requiring the injection of large quantities into oil reservoirs.

Economics, business, marketing, policy

13/01974 A review of the uncertainties in estimates of global oil resources

McGlade, G. E. *Energy*, 2012, 47, (1), 262–270.

This paper discusses the uncertainties that exist in estimating the remaining ultimately recoverable resources of oil globally including the reasons for these and, where possible, how they may be mitigated, resolved, or reduced in future assessments. The encompassing and ambiguous terms 'conventional oil' and 'unconventional oil' are disaggregated into the numerous categories of oil that exist within each. These categories are investigated individually in order to identify the specific uncertainties by which they are influenced and affected. A key finding is that there are intrinsic uncertainties within every category of oil. Future assessments of global oil resources and projections of oil production should hence acknowledge these issues, explain or assess the effects that they have on results, and present ranges in any estimates produced or provided. An initial estimate is made of the technically recoverable resources of the light tight oil often called 'shale oil': oil found in low permeability shale formations requiring stimulation to be extracted. These resources are estimated to range on a global scale between 150 and 508 billion barrels with a central estimate of 278 billion barrels.

13/01975 Crude oil price analysis and forecasting using wavelet decomposed ensemble model

He, K. *et al. Energy*, 2012, 46, (1), 564–574.

To improve the forecasting accuracy of crude oil price with deeper understanding of the market microstructure, this paper proposes a wavelet decomposed ensemble model. The proposed model follows the heterogeneous market hypothesis that assumes the unstationarity and dynamic changing nature of the underlying market structure and introduces the wavelet analysis to analyse the dynamic underlying data generating process at finer time scale domain. The simple averaging based ensemble model is introduced to reduce the estimation bias resulting from the use of different wavelet families by deriving market consensus view. The ensemble members are selected dynamically based on their in-sample performance among forecast matrices based on different wavelet families. Results from empirical studies show the superior performance of the proposed algorithm against the benchmark models, in terms of both level and directional predictive accuracy. The proposed model can effectively extract and model the time varying heterogeneous market microstructure, whose accurate characterization results in further improvement in market analysis and predictability.

13/01976 Downside risk and the energy hedger's horizon

Conlon, T. and Cotter, J. *Energy Economics*, 2013, 36, 371–379.

This paper explores the impact of investor time-horizon on an optimal downside hedged energy portfolio. The optimal heating oil hedge ratio is first calculated for a variety of downside risk objective functions at different time-horizons using the wavelet transform. Next, associated hedging effectiveness is contrasted for a range of risk metrics, with all metrics showing increasing hedging effectiveness at longer horizons. Moreover, decreased hedging effectiveness is demonstrated for increased levels of uncertainty at higher confidence intervals. While small differences in effectiveness are found across the different hedging objectives, time-horizon effects are found to dominate confirming the importance of the hedging horizon. The findings suggest that while downside risk measures are useful in determining an optimal futures hedge encompassing negative returns, hedging horizon and confidence intervals should also be given careful consideration by the energy hedger.

13/01977 Dynamic simulation of the BP Texas City refinery accident

Manca, D. and Brambilla, S. *Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 950–957.

The paper investigates the causes and simulates the dynamics of the events that led to the catastrophic explosion on 23 March 2005 at the BP refinery in Texas City, USA where 15 people died and 180 were injured. The paper follows the timeline of the accident, investigates the premises that characterized its phenomenology, and performs a critical analysis to fill the gaps that can be found in the scientific literature concerning the accident. In particular, a commercial dynamic process simulator was adopted and integrated with *ad hoc* models to explain the column flooding and overfilling, the opening of the relief valves, and the flow of a two-phase mixture into the pipe connected to the blowdown system. The main findings are: (1) that the mass balance and the liquid thermal expansion cannot explain the complete flooding and overflow of the isomerization column; (2) the vapour cap used to explain the column overflow appears to be unrealistic; (3) the overflow can be explained by the partial vaporization of the feed stream after 1:00pm and the consequent dispersion of vapour bubbles into the liquid holdup above the feed tray. In particular, tray holes smaller than 8 mm could cause the overflow; (4) there is a significant change in the thermodynamic conditions of the mixture emitted by the column head (temperature, pressure, vapour/liquid fractions) along the 270 m pipeline that connects the relief valves to the blowdown system; (5) the HEM model, together with the initial conditions applied cannot explain the blowdown drum filling and release, therefore further studies are necessary.

13/01978 Economic effects of peak oil

Lutz, C. *et al. Energy Policy*, 2012, 48, 829–834.

Assuming that global oil production peaked, this paper uses scenario analysis to show the economic effects of a possible supply shortage and corresponding rise in oil prices in the next decade on different sectors in Germany and other major economies such as the US, Japan, China, the OPEC or Russia. Due to the price-inelasticity of oil demand the supply shortage leads to a sharp increase in oil prices in the second scenario, with high effects on GDP comparable to the magnitude of the global financial crises in 2008/2009. Oil exporting countries benefit from high oil prices, whereas oil-importing countries are negatively affected. Generally, the effects in the third scenario are significantly smaller than in the second, showing that energy efficiency measures and the switch to renewable energy sources decreases the countries' dependence on oil imports and hence reduces their vulnerability to oil price shocks on the world market.

13/01979 Effects of oil production on economic growth in Eurasian countries: panel ARDL approach

Bildirici, M. E. and Kayikçi, F. *Energy*, 2013, 49, (1), 156–161.

This study aims at analysing the relationship between oil production and economic growth in major oil exporting Eurasian countries; Azerbaijan, Kazakhstan, Russian Federation and Turkmenistan for 1993–2010 periods. Empirical results reveal that oil production and economic growth are cointegrated for these countries. Furthermore, there is positive bi-directional causality between oil production and economic growth both in the long run and in the short run which supports the policies about investing in energy infrastructure.

13/01980 Exploring crude oil production and export capacity of the OPEC Middle East countries

Matsumoto, K. *et al. Energy Policy*, 2012, 48, 820–828.

As the world economy highly depends on crude oil, it is important to understand the dynamics of crude oil production and export capacity of major oil-exporting countries. Since crude oil resources are predominately located in the OPEC Middle East, these countries are expected to have significant leverage in the world crude oil markets by taking into account a range of uncertainties. This study develops a scenario for crude oil export and production using the ACEGES model considering uncertainties in the resource limits, demand growth, production growth, and peak/decline point. The results indicate that the country-specific peak of both crude oil export and production comes in the early this century in the OPEC Middle East countries. On the other hand, they occupy most of the world export and production before and after the peak points. Consequently, these countries are expected to be the key group in the world crude oil markets. It was also found that the gap between the world crude oil demand and production broadens over time, meaning that the acceleration of the development of ultra-deep-water oil, oil sands, and extra-heavy oil will be required if the world continuous to heavily rely on oil products.

13/01981 Gasoline prices, gasoline consumption, and new-vehicle fuel economy: evidence for a large sample of countries

Burke, P. J. and Nishitateno, S. *Energy Economics*, 2013, 36, 363–370.

Countries differ considerably in terms of the price drivers pay for gasoline. This paper uses data for 132 countries for the period 1995–2008 to investigate the implications of these differences for the consumption of gasoline for road transport. To address the potential for simultaneity bias, the authors use both a country's oil reserves and the international crude oil price as instruments for a country's average gasoline pump price. The authors obtain estimates of the long-run price elasticity of gasoline demand of between −0.2 and −0.5. Using newly available data for a sub-sample of 43 countries, they also find that higher gasoline prices induce consumers to substitute to vehicles that are more fuel-efficient, with an estimated elasticity of +0.2. Despite the small size of the elasticity estimates, there is considerable scope for low-price countries to achieve gasoline savings and vehicle fuel economy improvements via reducing gasoline subsidies and/or increasing gasoline taxes.

13/01982 Investments of oil majors in liquid biofuels: the role of diversification, integration and technological lock-ins

Oberling, D. F. *et al. Biomass and Bioenergy*, 2012, 46, 270–281.

The increasing use of liquid biofuels has been justified by highly volatile and rising oil prices, geopolitical instability of countries that control most of proven oil reserves, growing demand for passenger transportation and environmental concerns, especially climate change. Investments in the sector are increasing steadily, with oil majors being responsible for rising investments into liquid biofuel joint ventures, research and development projects and logistics. This paper analyses the underlying motivations of these investments by evaluating corporate diversification and integration strategies. Findings indicate that vertical integration and diversification are an integral part of oil major's strategic behaviour toward biofuels, although strategies differ substantially among companies. In the short term current major oil companies' investments in liquid biofuels are driven by the requirement to comply with binding mandates for biofuels, whereas in the long-term liquid biofuels, if produced on a significant scale, could be classified as non-conventional liquid hydrocarbon reserves for oil majors where access to other (non-)conventional resources is not secured. Finally, given existing technology lock-ins it seems unlikely whether different paths for producing liquid biofuels will be able to co-exist in the long term, or there will be only one dominant path possibly controlled by large oil companies.

13/01983 Modeling and forecasting the volatility of petroleum futures prices

Kang, S. H. and Yoon, S.-M. *Energy Economics*, 2013, 36, 354–362.

In study investigates volatility models and their forecasting abilities for three types of petroleum futures contracts traded on the New York Mercantile Exchange (West Texas Intermediate crude oil, heating oil #2, and unleaded gasoline) and suggest some stylized facts about the volatility of these futures markets, particularly in regard to volatility persistence (or long-memory properties). In this context, the authors examine the persistence of market returns and volatility simultaneously using the following ARFIMA–GARCH-class models: ARIMA–GARCH, ARFIMA–GARCH, ARFIMA–IGARCH, and ARFIMA–FIGARCH. Although the ARFIMA–FIGARCH model better captures long-memory properties of returns and volatility, the out-of-sample analysis indicates no unique model for all three types of petroleum futures contracts, suggesting that investors should be careful when measuring and forecasting the volatility (risk) of petroleum futures markets.

13/01984 Net oil exports embodied in China's international trade: an input–output analysis

Tang, X. *et al. Energy*, 2012, 48, (1), 464–471.

As the world's second largest oil importer, China has been one of the important factors which affect the global oil market. In recent years, China has attained great international trade surplus through exporting a large number of 'Made in China' products even during the global economic crisis. Due to direct and indirect effects in production chain, each 'Made in China' product contains oil directly or indirectly. China is exporting much oil through 'Made in China' products, which is not often considered even within China. An input–output model is established to calculate oil embodied in the international trade of China. The research results suggest the following: China's net oil exports embodied in the international trade were 87.02 million tonnes in 2007; manufacture of communication equipment, computers and other electronic equipment is the largest sector to export embodied oil; USA, Hong Kong and Netherlands are the top three countries and regions which benefit most from the embodied oil in 'Made in China' products. China's adjusted degree of dependence on foreign oil is 24.9% in 2007, and 38.4% in 2011 if net oil exports embodied in international trade are considered.

13/01985 Non-linearities in the dynamics of oil prices

Kisswani, K. M. and Nusair, S. A. *Energy Economics*, 2013, 36, 341–353.

Examining stationarity is of particular importance and represents the first step in empirical time-series research. Non-stationarity invalidates many of the results obtained from standard techniques and, therefore, requires special treatment. Because oil prices play an important role in affecting economic variables, this paper examines the stationarity of real oil prices (Brent, Dubai, WTI and the world) over the period 1973:2–2011:2. Real oil prices are expressed in the currencies of seven Asian countries (Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore and Thailand) and in the US dollar. While using linear unit root tests without structural breaks shows no evidence of stationarity, allowing for breaks shows very limited evidence of stationarity. The authors argue that these results are attributed to the presence of non-linearities in the behaviour of oil prices. Testing for non-linearity shows significant evidence of non-linearity in all the cases with evidence of exponential smooth transition autoregression non-linearity-type in most cases. Applying unit root tests that account for two types of non-linearities (smooth transition and non-linear deterministic trends) reveals evidence of stationarity in all the cases.

13/01986 Oil price effects on personal consumption expenditures

Wang, Y. S. *Energy Economics*, 2013, 36, 198–204.

This paper uses a logistic smooth transition model to examine the impact of rising oil prices on personal consumption expenditures in open and industrialized economies. The empirical results suggest a non-linear and asymmetric relation between oil price changes and personal consumption expenditures. In particular, the effects of rising oil prices on personal consumption expenditures are greater than those of falling oil prices. While oil price changes affect personal consumption expenditures via real balance effects, smooth transition effects also come into play. Below a threshold value, an increase in oil prices reduces personal consumption expenditures. In other words, in the face of uncertainty regarding future oil prices, consumers initially rationally postpone spending. However, once oil prices exceed the threshold value after a prolonged upward trend, the costs of domestic production factors rise. Continued price hikes increase personal consumption expenditure until a cost-pushed inflation takes hold. Due to differences in economic developments and structures, the effects of rising oil prices vary from one country to another. As a result, personal consumption expenditures also show various patterns across countries.

13/01987 On the dynamics of gasoline market integration in the United States: evidence from a pair-wise approach

Holmes, M. J. *et al. Energy Economics*, 2013, 36, 503–510.

This paper employs a pair-wise approach to examine regional integration in the US gasoline market. Using gasoline price data at the state level over a period of more than two decades, strong support was found for the view that the law of one price holds in regional markets, as more than 80% of bivariate price differentials turn out to be stationary. Furthermore, evidence was uncovered that the speed at which prices converge to the long-run equilibrium depends upon the distance between states. Asymmetries are also present in this relationship. The findings suggest that the more similar are states with respect to taxation, gas stations and refining capacity, the faster is the speed of adjustment towards the long-run equilibrium.

13/01988 U.S. stock returns and oil prices: the tale from daily data and the 2008–2009 financial crisis

Mollick, A. V. and Assefa, T. A. *Energy Economics*, 2013, 36, 1–18.

Using daily data from January 1999 to December 2011, US stock returns were examined (S&P 500, Dow Jones, NASDAQ, and Russell 2000) based on a wide range of information, including equity VIX volatility, inflation expectations, interest rates, gold prices, and the US$/€ exchange rate. The focus is on oil price returns, which have been previously found to exert mostly negative effects on US stock returns. Identifying the crisis of 2008–2009 as a significant period of economic contraction and subsequent 'recovery', the stability of the stock–oil relationship was checked by GARCH and MGARCH-DCC models. Prior to the financial crisis, stock returns are slightly (negatively) affected by oil prices and by the US$/€. For the subsample of mid-2009 onwards, however, stock returns are positively affected by oil prices and a weaker US$/€. As with inflation expectations, these findings were interpreted as US stocks responding positively to expectations of recovery worldwide. The proposed explanation is due to the changing correlation between stock markets and oil, either by standard GARCH models or by MGARCH-DCC models allowing the implied correlation to vary over time.

Derived liquid fuels

13/01989 An optimal design methodology for large-scale gas liquefaction

Li, Y. *et al. Applied Energy*, 2012, 99, 484–490.

This paper presents an optimization methodology for thermodynamic design of large scale gas liquefaction systems. Such a methodology enables configuration selection and parametric optimization to be implemented simultaneously. Exergy efficiency and genetic algorithm have been chosen as an evaluation index and an evaluation criterion, respectively. The methodology has been applied to the design of expander cycle based liquefaction processes. Liquefaction processes of hydrogen, methane and nitrogen are selected as case studies and the simulation results show that relatively high exergy efficiencies (52% for hydrogen and 58% for methane and nitrogen) are achievable based on very general consumptions.

13/01990 Combination of pyrolysis and hydroliquefaction of CCB-treated wood for energy recovery: optimization and products characterization

Kinata, S. E. *et al. Bioresource Technology*, 2012, 118, 315–322.

In this paper, pyrolysis and hydroliquefaction processes were successively used to convert chromium-copper-boron (CCB)-treated wood into bio-oil with respect to environment. Pyrolysis temperature has been optimized to produce maximum yield of charcoal with a high metal content (Cu, Cr, and B). The results obtained indicate that the pyrolysis at 300 °C and 30 min are the optimal conditions giving high yield of charcoal about 45% which contains up to 94% of Cu, 100% of Cr and 88% of B. After pyrolysis process, the charcoal has been converted into bio-oil using hydroliquefaction process. The optimization approach for the yield of bio-oil using a complete factorial design with three parameters: charcoal/solvent, temperature and hydrogen pressure was discussed. It is observed that the temperature is the most significant parameter and the optimum yield of bio-oil is around 82%. The metal analysis shows that the metals present in the bio-oil is very negligible.

13/01991 Direct formation of gasoline hydrocarbons from cellulose by hydrothermal conversion with *in situ* hydrogen

Yin, S. *et al. Biomass and Bioenergy*, 2012, 47, 228–239.

A new process based on aqueous-phase dehydration/hydrogenation (APD/H) has been developed to directly produce liquid alkanes ($C_{7–9}$), which are the main components of fossil gasoline, from cellulose in one single batch reactor without the consumption of external hydrogen (H_2). In this new process, part of the cellulose is first converted to *in situ* H_2 by steam reforming (SR) in the steam gas phase mainly; and, in the liquid water phase, cellulose is converted to an alkane precursor, such as 5-(hydroxymethyl)furfural (HMF). In the final reaction step, *in situ* H_2 reacts with HMF to form liquid alkanes through APD/H. Accordingly, this new process has been named SR(H_2)-APD/H. Experimental results show that the volumetric ratio of the reactor headspace to the reactor (H/R) and an initial weakly alkaline condition are the two key parameters for SR(H_2)-APD/H. With proper H/R ratios (e.g. 0.84) and initial weakly alkaline conditions (e.g. pH = 7.5), liquid alkanes are directly formed from the SR(H_2)-APD/H of cellulose using *in situ* H_2 instead of external H_2. In this study, compared with pyrolysis and hydrothermal liquefaction of cellulose at the same temperatures with same retention time, SR(H_2)-APD/H greatly increased the liquid alkane yields, by approximately 700 times and 35 times, respectively. Based on this process, direct formation of fossil gasoline from renewable biomass resources without using external H_2 becomes possible.

13/01992 Influence of sulfonated acetone–formaldehyde condensation used as dispersant on low rank coal–water slurry

Li, R. *et al. Energy Conversion and Management*, 2012, 64, 139–144.

A water-soluble aliphatic polymer, sulfonated acetone–formaldehyde (SAF) condensation, was developed by sulfonation and polycondensation reaction. To determine the optimum molecular structure of SAF dispersant for preparing the minimum viscosity of highly concentrated low-rank coal–water slurry (CWS), various SAF with different sulfonic group content and different molecular weight were prepared by controlling the quantity of sulfonating agent and the mass concentration of reaction solution. The CWS followed three-parameter Herschel–Bulkley model and behaved as a non-Newtonian fluid in the presence of SAF. Compared with naphthalene sulfonate formaldehyde condensation, SAF had a better effect in reducing the viscosity, especially for the SAF with molecular weight of 31,800–36,800 and the sulfonic group content of 3.53–3.64 mmol/g. The effectiveness of viscosity reduction for CWS had been attributed primarily to the diminution of the coal particle–particle interaction because of steric hindrance and electrostatic repulsion, which were offered by adsorbed SAF. The effect was further proved by zeta potential measurements of coal and rheological investigation of slurry in the presence of SAF.

13/01993 Investigation on a novel reactor for gas hydrate production

Rossi, F. *et al. Applied Energy*, 2012, 99, 167–172.

Gas hydrates have a large capacity for the storage of gases and are an attractive method for gas filtration and transportation. However, hydrate formation is usually controlled by the rate of crystallization and thus it can be a slow process. A technology that will rapidly and continuously form hydrate is necessary for scale-up. A novel reactor with an inner volume of 25 litres has been designed, built and installed to form hydrates by injection of water through spray nozzles from the top of the methane-filled reactor. This method allows to maximize interfacial area between reactants and to minimize mass transfer barriers and thermal effects that negatively affect conversion of reactants into hydrate. A system was developed to remove heat released during hydrate formation, and to reach a good level of temperature control inside the reactor. A novel system for hydrate recovering and unloading was also designed. The objective of experimentation is to lower energetic costs of hydrate formation, also through surfactant promotion. Anionic surfactant sodium dodecyl sulfate was tested. Results of a first set of experimental applications of the reactor for rapid methane hydrate formation are presented.

13/01994 Performance assessment of organic-based synthetic calcium and boric acid modified bitumens

Arslan, D. *et al. Fuel*, 2012, 102, 766–772.

This study investigates the modification of bitumen separately with two novel additive materials: organic-based calcium compound (OBCC) and organic-based boric acid compound (OBBAC). These compounds were synthesized chemically at laboratory conditions. At a 50/70 penetration grade bitumen was modified with OBCC and OBBAC at the concentrations of 1% (w/w), 2% (w/w), 3% (w/w), 5% (w/w) and 10% (w/w). Conventional (softening point, ductility, Marshall, Nicholson stripping, indirect tension) and superpave test methods (rotational viscosity, bending beam rheometer, dynamic shear rheometer) were performed to determine the effects of the additives on the bitumen and bituminous mixture properties. The proper content of each additive was determined as 3% (w/w) based on the rotational viscosity test results. The viscosity and softening point were decreased and ductility was increased by OBCC and OBBAC. High temperature performances of the modified bitumens provide the same level with original bitumen according to DSR test results. BBR tests have showed that better low temperature cracking resistance was obtained through OBCC and OBBAC modifications. Marshall Stability, stripping resistance and stiffness modulus of the bituminous mixtures were determined to be improved by both of the additives.

13/01995 Process optimization for microwave-assisted direct liquefaction of *Sargassum polycystum* C. Agardh using response surface methodology

Guo, J. *et al. Bioresource Technology*, 2012, 120, 19–25.

Response surface methodology (RSM) was used to optimize the microwave-assisted direct liquefaction of *Sargassum polycystum* C. Agardh in ethylene glycol (EG) with H_2SO_4 as a catalyst. Based on the results of single factor experiments, EG-to-feedstock ratio, temperature and catalyst content were chosen as independent variables for a central composite rotatable design (CCRD). The optimal liquefaction conditions were estimated as: the EG-to-feedstock ratio of 18.50:1 (w/w), the temperature of 170 °C, the reaction time of 15 min, catalyst content of 9.6% (catalyst/EG, w/w%) and microwave power of 400 W with the liquefaction yield of 87.70%. The bio-oils were mainly composed of fatty acid methyl ester and alkane with a long chain from C_{17} to C_{20}.

13/01996 Production of Fischer–Tropsch fuels and electricity from bituminous coal based on steam hydrogasification

Lu, X. *et al. Energy*, 2012, 48, (1), 525–531.

A new thermochemical process for Fischer–Tropsch (FT) fuels and electricity coproduction based on steam hydrogasification is addressed and evaluated in this study. The core parts include steam hydrogasification reactor (SHR), steam methane reformer (SMR) and FT reactor (FTR). A key feature of SHR is the enhanced conversion of carbon into methane at high steam environment with hydrogen and no need for catalyst or the use of oxygen. Facilities utilizing bituminous coal for coproduction of FT fuels and electricity with carbon dioxide sequestration are designed in detail. Cases with design capacity of either 400 or 4000 tonnes/day (dry basis) are investigated with process modelling and cost estimation. A cash flow analysis is performed to determine the fuels (production cost) PC. The analysis shows that the 400 tonnes/day case due to a FT fuels PC of $5.99/gallon diesel equivalent results in a plant design that is totally uneconomic. The 4000 tonnes/day plant design is expected to produce 7143 bbl/day FT liquids with PC of $2.02/gallon and $2.27/gallon diesel equivalent at overall carbon capture ratio of 65% and 90%, respectively. Prospective commercial economics benefits with increasing plant size and improvements from large-scale demonstration efforts on steam hydrogasification.

13/01997 Production of Fischer–Tropsch liquid fuels from high temperature solid oxide co-electrolysis units

Becker, W. L. *et al. Energy*, 2012, 47, (1), 99–115.

A model for high temperature co-electrolysis (HTCE) of carbon dioxide and water using solid oxide electrolytic cells (SOEC) for syngas production and subsequent conversion to liquid fuels by a Fischer–Tropsch (F–T) process is presented. The SOEC model is guided by experimental data from the literature, and the model is employed to explore the effect of temperature, pressure, and feedstock composition on syngas composition exiting the SOEC. The syngas is converted in a slurry bubble column F–T synthesis reactor in which the model approach of a once-through conversion of carbon monoxide is chosen, and the distribution of hydrocarbon products is determined by the Anderson–Schulz–Flory model. The overall system efficiency for liquid hydrocarbon fuels produced from electrical energy is found to be 54.8% HHV (51.0% LHV). It is determined that operating the SOEC at low pressure (1.6 bar) versus higher pressure (5 bar) results in an efficiency gain of 2.6%. The economics of the production plant are evaluated for variations in electricity feedstock costs and operating capacity factors. The liquid fuels production costs range from $4.4 to 15.0GGE for electricity prices of $0.02 to 0.14/kWh and a plant capacity factor of 90% to 40%, respectively.

13/01998 Simultaneous hydrogen injection and in-situ H_2O removal in a novel thermally coupled two-membrane reactor concept for Fischer–Tropsch synthesis in GTL technology

Bayat, M. *et al. Journal of Natural Gas Science and Engineering*, 2012, 9, 73–85.

Gas-to-liquids (GTL) technology converts natural gas, through Fischer–Tropsch synthesis, into liquid and ultra-clean hydrocarbons such as gasoline, light oils, naphtha, diesel, and wax. In this study, a novel thermally coupled multi-tubular two-membrane reactor (TCTMR) is proposed in order to enhance of gasoline production. Fischer–Tropsch synthesis is carried out in the exothermic side with two different membranes and supplies the necessary heat for the endothermic side. Decomposition of ammonia is carried out in the endothermic side with hydrogen-permselective Pd/Ag membrane layer. Therefore, the proposed reactor consists of two different membranes, one for permeation of pure hydrogen from exothermic into endothermic side and another one for separation of water from exothermic side. Water produced during FTS negative influences the reaction by re-oxidation of catalysts, increasing water/gas shift activity and decreasing partial pressures of the products. A steady-state heterogeneous model of the two fixed beds predicts the performance of this novel configuration. The achieved results of this simulation have been compared with the results of the conventional fixed-bed reactor (CR) at identical process conditions. The simulation results show 27.14% enhancement in the gasoline yield and 35.2% decrease in CO_2 yield of TCTMR in comparison with the one in CR due to a favourable profile of temperature along the TCTMR.

13/01999 Upgrading peat to gas and liquid fuels in supercritical water with catalysts

Xu, C. and Donald, J. *Fuel*, 2012, 102, 16–25.

Peat was effectively upgraded into gas and liquid fuels by supercritical water treatment at 380–440 °C with and without catalyst. Treatment of the peat without using catalyst at a temperature ranging from 350 to 440 °C generally led to 5–10 wt% yield of water soluble oil (WSO), about 15 wt% yield of heavy oil (HO), 20–27 wt% yield of gas and 20–30 wt% yield of char. As expected, the gas yield increased and the yields of oils and char generally decreased at a higher operation temperature. The optimal conditions for a greater HO yield appeared to be a lower residence time and a lower water-to-peat ratio (i.e. a higher initial biomass concentration). Among all the catalysts tested including 0.1 M K_2CO_3, 0.1 M $FeSO_4$, 0.1 M RuO_2, and 0.1 M and 1.0 M $Ca(OH)_2$, 0.1 M $Ca(OH)_2$ was found the most effective for enhancing the production of liquid oils of both HO and WSO. The presence of 1.0 M $Ca(OH)_2$ at 410 °C produced extremely low CO_2 yield, due to the adsorption reaction of CO_2 over the $Ca(OH)_2$ catalyst, and a fourfold increase in H_2, resulting in a high quality gas product with a HHV of 27.7 MJ/kg, as oppose to only 2.81 MJ/kg for the gas product without catalyst. Among all the catalysts tested, RuO_2 proved to be the best catalyst for upgrading peat to H_2-rich gas products, and the formation of H_2 attained as high as 2.44 mmol/g with 0.1 M RuO_2 at 410 °C, compared with 0.05 mmol/g without catalyst. The HOs obtained from the SCW treatments, rich in phenolic compounds and fatty acids, possess much greater caloric values (with a HHV of >33–35 MJ/kg) than the dried peat powder used (with a HHV of about 21 MJ/kg).

13/02000 Utilization of cyclohexanol dehydrogenation in a novel thermally coupled reactor for Fischer–Tropsch synthesis in gas to liquid technology

Rahimpour, M. R. *et al. Journal of Natural Gas Science and Engineering*, 2012, 9, 138–148.

In this study, the dehydrogenation of cyclohexanol (CLL) and its utilization in a novel thermally coupled reactor for Fischer–Tropsch synthesis (FTS) has been investigated. In the new configuration, the produced heat of FTS reactions is removed by the endothermic reaction of CLL dehydrogenation instead of circulating high-pressure boiling water in the conventional reactor (CR). The products of this reaction are hydrogen and cyclohexanone (CLN). Some of the generated hydrogen is utilized in synthesis gas and also in hydro cracking unit for production of GTL products and other is stored and used in some other processes. Gasoline (C_+^5) – the desirable product – alongside some undesirable products like carbon dioxide and methane are produced in FTS reactions. To demonstrate the superiority and advantages of this new configuration it has been compared with another thermally coupled reactor for FTS in which the dehydrogenation of cyclohexane works as coolant reaction in the endothermic side of the reactor. In order to analyse this novel reactor a one-dimensional heterogeneous model has been applied. After modelling and solving the differential equations, the excellence and advantages of new configuration are clarified. The (C_+^5) yield is increased and a reduction in the generation of undesirable products like CO_2 and CH_4 is observed in this new configuration. Moreover, hydrogen and CLN which both are useful products are generated in considerable amounts in the endothermic side of the reactor.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

13/02001 Assessment of calorific value at a gas transmission network

Tsochatzidis, N. A. and Karantanas, E. *Journal of Natural Gas Science and Engineering*, 2012, 9, 45–50.

A method to determine the combined calorific value uncertainty of a number of chromatographic systems, in order to assess their performance, is proposed. Using this method the uncertainty of calorific value, determined from gas analysis of various chromatographic systems at the central – north region of the Hellenic Gas Transmission System, is estimated. Real gas calorific value data, from the same chromatographic systems of the selected region, are then evaluated. Analysis of data reveals that calorific values of natural gas are measured within acceptable tolerance for the systems studied. This uncertainty estimation method can be applied for various regions of gas transmission systems and time periods, with similar characteristics.

13/02002 Estimation of natural gas compressibility factors using artificial neural network approach

Sanjari, E. and Lay, E. N. *Journal of Natural Gas Science and Engineering*, 2012, 9, 220–226.

Prediction of compressibility factor of natural gas is an important key in many gas and petroleum engineering calculations. In this study compressibility factors of different compositions of natural gas are modelled by using an artificial neural network (ANN) based on back-propagation method. A reliable database including more than 5500 experimental data of compressibility factors is used for testing and training of ANN. The designed neural network can predict the natural gas compressibility factors using pseudo-reduced pressure and pseudo reduced temperature with average absolute relative deviation percentage of 0.593. The accuracy of designed ANN has been compared to the mostly used empirical models as well as equations of state of Peng–Robinson and statistical association fluid theory. The comparison indicates that the proposed method provide more accurate results relative to other methods used in this work.

13/02003 Non-Gaussian gas hydrate grade simulation at the Mallik site, Mackenzie Delta, Canada

Dubreuil-Boisclair, C. *et al. Marine and Petroleum Geology*, 2012, 35, (1), 20–27.

For the past decades, gas hydrate reservoirs have beneficiated from an increasing attention in the academic and industrial worlds. As a result, there is a growing need to develop specific and comprehensive gas hydrate reservoir characterization methods. This study explores the use of a stochastic Bayesian algorithm to integrate well-logs and three-dimensional (3D) acoustic impedance in order to estimate gas hydrate grades (product of saturation and total porosity) over a representative volume of the Mallik gas hydrate field, located in the Mackenzie Delta, Northwest Territories of Canada. First, collocated log data from boreholes Mallik 5L-38 and 2L-38 are used to estimate the statistical relationship between acoustic impedance and gas hydrate grades. Second, conventional stochastic Bayesian simulation is applied to generate multiple gas hydrate grade 3D fields integrating log data and lateral variability of 3D acoustic impedance. These equiprobable scenarios permit to quantify the uncertainty over the estimation, and identify zones where this uncertainty is greater. Contrary to conventional stochastic reservoir modelling workflows, the proposed method allows integrating non-Gaussian and non-linear distributions. This permits to handle bimodal distributions without using complex stochastic transforms. The results present gas hydrate grade values that are in accordance with well-log data. The relatively low standard deviation calculated at each pixel using all realizations suggests that gas hydrate grades is well explained by acoustic impedance and log data.

13/02004 Prediction of transient pressure response in the petroleum reservoirs using orthogonal collocation

Vaferi, B. *et al. Journal of Petroleum Science and Engineering*, 2012, 98–99, 156–163.

Diffusivity equation is one of the most widely used equations in petroleum engineering. It is basically derived to predict the dynamic pressure response and behaviour of fluids flow in porous media with respect to time and position. The main objective of this study is the feasibility of applying of orthogonal collocation (OC) method to solve diffusivity equation in the radial transient flow system. OC is an approximate analytical approach which categorizes in the weighted residuals methods. The advantage and priority of this method over numerical or exact analytical solution (i.e. Laplace transform) is in the cases which the heterogeneity and variation of reservoir properties such as porosity and permeability with position or pressure could not be neglected, in these situations, the numerical or exact analytical solution is very tedious and may be impossible. The diffusivity equation for an oil reservoir which obtained from literature has been solved by both OC and exact analytical solutions. To demonstrate the reliability of the proposed method, the results of this method have been compared with those achieved using exact analytical solution. Mean absolute deviation percentage (MADP%) has been used for determining the suitable number of collocation points to give acceptable error and best matching between approximate and analytical results. Sensitivity analysis indicates that increasing the number of collocation points result in significant improvement in its accuracy and capability on dynamic pressure prediction. The minimum MADP% of 0.1047 from the exact analytical predictions has been obtained by 20 collocation points. The results indicate that the proposed approximate method with these numbers of collocation points can predict the reservoir pressure trend with an acceptable accuracy.

13/02005 Seismic velocities on the Nova Scotian margin to estimate gas hydrate and free gas concentrations

Schlesinger, A. *et al. Marine and Petroleum Geology*, 2012, 35, (1), 105–115.

This article provides new constraints on gas hydrate and free gas concentrations in the sediments at the margin off Nova Scotia. Two-dimensional (2-D) velocity models were constructed through simultaneous travel-time inversion of ocean-bottom seismometer (OBS) data and 2-D single-channel seismic (SCS) data acquired in two surveys, in 2004 and 2006. The surveys, separated by ~5 km, were carried out in regions where the bottom-simulating reflection (BSR) was identified in seismic reflection datasets from earlier studies and address the question of whether the BSR is a good indicator of significant gas hydrate on the Scotian margin. For both datasets, velocity increases by 200–300 m/s at a depth of approximately 220 m below seafloor (mbsf), but the results of the 2006 survey show a smaller velocity decrease (50–80 m/s) at the base of this high-velocity layer (310–330 mbsf) than the results of the 2004 survey (130 m/s). When converted to gas hydrate concentrations using effective medium theory, the 2-D velocity models for both datasets show a gas hydrate layer of ~100 m thickness above the identified BSR. Gas hydrate concentrations are estimated at approximately 2–10% for the 2006 data and 8–18% for the 2004 survey. The reduction in gas hydrate concentration relative to the distance from the Mohican Channel structure is most likely related to the low porosity within the mud-dominant sediment at the depth of the BSR. Free gas concentrations were calculated to be 1–2% of the sediment pore space for both datasets.

13/02006 Trace back of depleted-saturated lean gas condensate reservoir original fluid: condensate stabilization technique

Nematollahi, M. *et al. Journal of Petroleum Science and Engineering*, 2012, 98–99, 164–173.

Gas condensate reservoirs denote an important source of hydrocarbon reserves and have long been identified as a reservoir type, possessing the most complicated flow and complex thermodynamic behaviours. On the other hand, collection of a sample that dependably represents the reservoir fluid is vital in simulation and flow behaviour considerations particularly for gas condensate reservoir fluids. Because of multiphase flow in near well bore region, even during early depletion stages, recombined separator or directly obtained bottom-hole samples may not represent original reservoir fluid. The problem becomes more complex when the average pressure declines below saturation one and consequently condensate saturation distributes in whole drainage area. As a consequent, reservoir fluid should be sampled as early as possible during the production life of a reservoir. This paper presents a novel and relatively simple method for determination of representative initial fluid of a depleted-saturated lean gas condensate reservoir, using at least available data of original fluid including dew point pressure and producing GOR properties. The procedure was supported by thermodynamic PVT programs and reservoir simulations. An equation of state based PVT program was expertly tuned with properties of an assumed initial fluid sample and was used in the phase behaviour deliberation and reservoir simulation. Suitable conditions for sampling are also investigated. Comparative studies show that recombination with simultaneous matching of GOR and dew point pressure can trace back initial reservoir fluid acceptably.

Transport, storage

13/02007 A PROMETHEE-GDSS for oil and gas pipeline planning in the Caspian Sea basin

Tavana, M. *et al. Energy Economics*, 2013, 36, 716–728.

The demand for oil and natural gas has severely challenged the world supply. The Caspian Sea basin holds large quantities of both oil and natural gas. Pipelines are needed to transport the oil and natural gas from this landlocked region over long distances within countries and across borders to meet this increasing demand. The evaluation of alternative export routes in the Caspian Sea basin is a complex multicriteria problem with conflicting objectives. The authors present a group decision support system (GDSS) for the evaluation of alternative pipeline routes in this region. The proposed system decomposes the route selection process into manageable steps. The system combines strength, weakness, opportunity and threat (SWOT) analysis with the Delphi method to capture the decision-makers' beliefs. A group preference ranking organization method for enrichment evaluation (PROMETHEE) model is used to integrate these beliefs with subjective judgments and identify the most attractive pipeline route. The geometrical analysis for interactive assistance (GAIA) plane is used to further analyse the alternative routes and arrive at a group solution consistent with managerial goals and objectives. The GDSS provided here promotes a wider understanding of the available choices and the necessary compromises needed to achieve a better decision outcome. The framework developed in this study can potentially lend itself to many practical applications. However, there are a number of challenges involved in the proposed research that provide a great deal of possibilities for future research. For example, incorporating simulation and optimization methods in the GDSS developed in this study will allow decision-makers to point out advanced economic analysis, technical design, or environmental impact estimation. Although the benefits of this GDSS are still emerging, the potential is enormous.

13/02008 An information diffusion-based model of oil futures price

Li, Z. *et al. Energy Economics*, 2013, 36, 518–525.

Inspired by the increasing evidence of financialization/speculation in commodity pricing, this paper constitutes a first attempt to build an information diffusion-based asset pricing framework for the oil futures market. With gradual information dissemination, slowly decaying uncertainty about the asset's future fundamentals generates persistent conditional volatility and a drift in asset return. Volatility-based proxies for information flows are proposed to examine empirically the asset pricing implications. The results confirm a significant intertemporal relationship between return on the price of oil futures, information diffusion and volatility components. An important implication of this study is that the slow diffusion of information generates predictability in price dynamics. A forecasting model is then constructed and tested in relation to the theory. It was found that the lagged series of the pricing factors possessed significant predicting power for returns.

13/02009 Bio-electrochemical conversion of carbon dioxide to methane in geological storage reservoirs

Sato, K. *et al. Energy Conversion and Management*, 2013, 66, 343–350.

Geological storage of carbon dioxide (CO_2) as currently conceived is not commercially viable. To promote deployment of CO_2 capture and storage (CCS), substantial value must be added to CCS operations. The authors have proposed a subterranean carbon plantation that involves storing CO_2 in a geological reservoir, biologically converting the stored CO_2 to methane *in situ*, and harvesting the biogenic methane as a recycled energy source. To examine the durability of methanogenic metabolism under storage reservoir conditions, the methanogenic activity of *Methanothermobacter thermautotrophicus* (a representative subsurface methanogen) was assessed under nutrient-limited and reduced-pH conditions in actual formation-water-based media. Moreover, to examine the possibility of electrochemically supplying the source of reducing power into the reservoir, methanogen was also incubated in absence of exogenously supplied molecular hydrogen with applied voltage. Applied-voltage-dependent methanogenesis was observed, suggesting that methanogen can utilize electrons and protons as a reducing-power source to reduce CO_2 to methane. Towards practical deployment of the electromethanogenic system to utilize CCS reservoirs as energy-reserving tanks, further studies are required to enhance the bio-electromethanogenic activity and optimize well configurations.

13/02010 Exergy and exergoeconomic evaluation of gas separation process

Ghorbani, B. *et al. Journal of Natural Gas Science and Engineering*, 2012, 9, 86–93.

Exergy and exergoeconomic analyses for product recovery and separation systems of natural gas plant as well as the refrigeration system required for the plant are carried out. The exergetic and exergoeconomic costs of all process and utility streams are calculated through a systematic method of assigning exergetic cost relations to the streams. The results indicate that the exergetic efficiencies of the Debutanizer, Depropoanizer, and De-ethanizer columns are the lowest. Distillation columns have 64% of the total exergy loss, which is the maximum value of the system components. In the second place, heat exchangers have 15% of the exergy loss. Next there are compressors and expanders which have 13% and 6% of the exergy loss, respectively. It should be noted that the expander is replaced by a choke valve for energy-saving purposes. On the other hand, the results of the exergoeconomic analysis show that the percentage increases in the unit thermoeconomic costs of the compression and the Demethanizer sections are the highest. This study demonstrates that the exergoeconomic analysis, whose results present cost-based information suggesting potential locations for the process improvement, can provide more information in comparison to the exergy analysis.

13/02011 Impact assessment of traffic-induced vibration on natural gas transmission pipeline

Bajcar, T. *et al. Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 1055–1068.

The purpose of this paper is to present a study of impact assessment of the traffic-induced vibration on a buried natural gas transmission pipeline. The basic assumption in this study is that the traffic on pipeline-transportation route crossing might have a significant impact on natural gas pipeline structural integrity due to the traffic-induced vibration which propagates from the road surface through the soil and excites the buried natural gas pipeline. The resulting dynamic stress causes pipeline material fatigue loading which consequently may cause pipeline failure with the gas release into the environment exposing the population and the buildings in pipeline vicinity to a significant threat. The experiment on operating buried natural gas pipeline was conducted where measurements were performed on the road surface, the two operating buried natural gas pipelines of external diameter 500 and 250 mm and on corresponding casing pipes. The measurement data analysis was performed and the results were used for determination of pipeline lifetime period in the model for theoretical estimation of pipeline lifetime which has been exposed to traffic-induced vibration. The findings of the study in this paper show that the traffic-induced vibration on given buried natural gas pipeline is detectable, however this vibration, compared to the other factors which are influencing pipeline's structural integrity, does not have a significant impact on pipeline lifetime period.

13/02012 Purposefully built underground natural gas storage

Wang, X. and Economides, M. J. *Journal of Natural Gas Science and Engineering*, 2012, 9, 130–137.

The volumes of natural gas that are needed for a wide variety of industrial processes plus domestic uses vary significantly with respect to time, location, and demand. Thus, mechanical storage of natural gas in manufactured containers is not economically feasible or even logistically possible. Although much of the storage and withdrawal have been associated with seasonality, storage is becoming essential in an integrated natural gas supply network. It is particularly important in large operations, such as being a backup fuel in power generation and in sustaining the rate for liquefied natural gas production. Therefore, the design of underground natural gas storage becomes essential. Important components of natural gas storage engineering include capacity which is affected by reservoir volume and tolerable pressure; injection or producing rates which are affected by reservoir permeability, natural reservoir drive mechanism, well completion/stimulation; and the impact of cyclical losses. The authors present here a new sequence of calculations and estimations for monitoring and forecasting gas movements through an underground gas storage reservoir: maximum capacity estimation with a new type of graphical construction, blending concepts of the classical p/Z vs cumulative recovery straight line in natural gas production; prediction of withdrawal rates and time, constrained by decreasing storage pressure; determination of maximum or sustainable withdrawal rate for a period of time. In all cases considered, the injecting and producing wells are hydraulically fractured. The hydraulic fractures are designed for the withdrawal rate. Thus, the required number of wells is determined. The authors apply these concepts to an underground natural gas storage facility and forecast the injection and production rates, cumulative storage and withdrawal, pressure build-up and decline as a function of time. A case study is presented here to demonstrate an appropriate sequence for designing an underground natural gas storage facility so that it can meet certain functionalities. In this case, the underground storage facility needs to provide enough gas to support a 1000 MW gas-fired power plant for continuous 90-day operating period (in the case of emergency).

Economics, business, marketing, policy

13/02013 A cascaded fuzzy-LOPA risk assessment model applied in natural gas industry

Khalil, M. *et al. Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 877–882.

Natural gas plants demand high amount of energy provided through immense fuel gas units that may suffer risk hazards. Implementing a safety management system is the most efficient way of allocating resources for safety. This paper adopts the layer of protection analysis (LOPA) risk management associated with fuzzy logic methodology to prevent or limit industrial accidents. The authors provide an innovative cascaded fuzzy-LOPA model for certain hazardous scenarios and at different frequencies of occurrence. The introduced model is tested at moderate and high risk levels controlled in its practical limits through the use of safety integrity functions. Obtained results show how this fuzzy-LOPA achieves better results to maintain the safety integrity level rating to acceptable limits.

13/02014 A review of national gas emergency plans in the European Union

Zeniewski, P. and Bolado-Lavin, R. *Energy Policy*, 2012, 49, 652–662.

The purpose of this paper is to document and review existing national gas emergency plans in the European Union (EU), following the guidelines and requirements set out by the EU's Regulation 994/2010 concerning measures to safeguard security of gas supply. Despite the great deal of attention paid to questions of natural gas security in an increasingly import-dependent EU, the contingency plans of most of its member states have not been widely published or scrutinized. By reviewing TSO network codes and national legal and regulatory acts, this paper teases out the key similarities and differences between member states' emergency planning frameworks, tools and methods. A gas emergency operational template is subsequently proposed that conforms to EU legislation. This is followed by a discussion of emergency planning in the context of regional cooperation and the liberalizing European gas market. The paper concludes by advocating gas emergency measures which are proportionate to the crisis level, sensitive to the gas demand profile, aware of the regional context, inconsequential to normal market operation, transparent and non-discriminatory during implementation and verifiable during emergencies as well as under normal conditions.

13/02015 A survey on gas leak detection and localization techniques

Murvay, P.-S. and Silea, I. *Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 966–973.

Gas leaks can cause major incidents resulting in both human injuries and financial losses. To avoid such situations, a considerable amount of effort has been devoted to the development of reliable techniques for detecting gas leakage. Many leak-detecting techniques are available for gas pipelines. Some techniques have been improved since their first proposal and some new ones have been designed as a result of advances in sensor manufacturing and computing power. However, each detection method comes with its advantages and disadvantages. Leak detection techniques in each category share some advantages and disadvantages. For example, all external techniques which involve detection done from outside the pipeline by visual observation or portable detectors are able to detect very small leaks and the leak location, but the detection time is very long. Methods based on the mathematical model of the pipe have good results at high flow rates while at low flow rates a mass balance based detection system would be more suitable. Regarding costs, most of the available techniques are expensive, although this disadvantage is likely to disappear for some of these techniques due to forthcoming technological advancements. Combining several leak detection systems is a common practice and also a recommendation in order to cope with the presented disadvantages. Hybrid systems benefiting from the real-time detection capability of a software based method and the high localization accuracy of a hardware based technique, along with other specific advantages of both approaches, seem to be the future trend in gas leak detection. Selecting from the wide variety of commercial solutions available is ultimately an action that has to be taken after assessing the needs of the system in which gas leak detection is needed.

13/02016 Baseline measurements of ethene in 2002: implications for increased ethanol use and biomass burning on air quality and ecosystems

Gaffney, J. S. *et al. Atmospheric Environment*, 2012, 56, 161–168.
While it is well known that combustion of ethanol as a biofuel will lead to enhanced emissions of methane, ethene (ethylene), acetaldehyde, formaldehyde, and oxides of nitrogen (primarily NO) when compared to gasoline alone, especially during cold starts or if catalytic converters are not operating properly, the impacts of increases in atmospheric ethene levels from combustion of fuels with higher ethanol content has not received much attention. Ethene is a well-known and potent plant growth hormone and exposure to agricultural crops and natural vegetation results in yield reductions especially when combined with higher levels of PAN and ozone also expected from the increased use of ethanol/gasoline blends. The authors report here some baseline measurements of ethene obtained in 2002 in the south-western and south central USA. These data indicate that current ethene background levels are less than 1 ppb. Anticipated increases in fuel ethanol content of E30 or greater is expected to lead to higher atmospheric levels of ethene on regional scales due to its atmospheric lifetime of 1.5–3 days. These background measurements are discussed in light of the potential enhancement of ethene levels expected from the anticipated increases in ethanol use as a renewable biofuel.

13/02017 Cost-effective biogas utilisation – a modelling assessment of gas infrastructural options in a regional energy system

Börjesson, M. and Ahlgren, E. O. *Energy*, 2012, 48, (1), 212–226.
The current utilization of biogas from anaerobic digestion is low compared to the technical potential. This study investigates requirements for policy support to overcome techno-economic barriers of biogas utilization and effects of different biogas distribution strategies. Two potential sectors for biogas use are covered: the transport sector and the district heating sector. A quantitative, optimizing, energy system modelling approach is applied and the region of Västra Götaland, Sweden, is studied. The model has a high geographical resolution and locations of both biogas feedstock and potential markets are taken into account. The results show that a small part of the technical biogas potential can be cost-effectively utilized without biogas subsidies or larger infrastructural investments. Comparably low subsidies give significant increases in cost-effective biogas utilization levels, but utilization close to the full technical potential is linked to high subsidies. From a techno-economic perspective, biogas is best used as vehicle gas. Since local vehicle gas markets are limited, enhanced biogas distribution conditions not only imply larger total cost-effective biogas utilization, but also a larger share of biogas as vehicle gas. Compared to distribution strategies based on truck transports and regional biogas grids, an expanded natural gas grid presents possibilities but also risks.

13/02018 Do food and oil prices co-move?

Reboredo, J. C. *Energy Policy*, 2012, 49, 456–467.
This paper studies co-movements between world oil prices and global prices for corn, soybean and wheat using copulas. Several copula models with different conditional dependence structures and time-varying dependence parameters were considered. Empirical results for weekly data from January 1998 to April 2011 showed weak oil-food dependence and no extreme market dependence between oil and food prices. These results support the neutrality of agricultural commodity markets to the effects of changes in oil prices and non-contagion between the crude oil and agricultural markets. However, dependence increased significantly in the last three years of the sampling period, even though upper tail dependence remained insignificant, indicating that food price spikes are not caused by positive extreme oil price changes. These results have implications for policy design, risk management and hedging strategies.

13/02019 Does natural gas fuel price cause system marginal price, vice-versa, or neither? A causality analysis

Chae, Y. *et al. Energy*, 2012, 47, (1), 199–204.
Faced with ever-increasing demand for electricity, policymakers in South Korea plan to introduce a new tariff regime that properly reflects the varying costs of generation in the wholesale power market. Since it is crucial to have supporting empirical evidence for this regime, this study attempts to investigate the nature of long- and short-run causality between liquefied natural gas (LNG) fuel price for generation and wholesale power price in Korea. To this end, the authors apply the time-series techniques of unit-root and co-integration tests, as well as error-correction modelling using monthly data from April 2001 to January 2011. The results indicate that there is a unidirectional causal relationship running from LNG fuel price to wholesale electricity price in both the short and the long run. Strong causality in the same direction is also detected. This means that an increase in LNG fuel price directly affects wholesale power price. Therefore, Korean policymakers should take more consideration of LNG fuel price for generation when they design and implement any future retail indexation tariff regime.

13/02020 Efficient mechanisms for access to storage when competition in gas markets is imperfect

Cavaliere, A. *et al. Energy Economics*, 2013, 36, 481–490.
Scarce storage capacity and distortions in access to storage can lead to market foreclosure in liberalized gas markets. This study considers rules currently adopted in Europe for storage allocation, and discuss efficient rationing mechanisms as based on the value of storage, when other flexibility inputs are partially available. They authors initially analyse productive efficiency issues, without explicitly considering vertical restraints. They then assume imperfect competition in the downstream market for gas supplies, given the availability of storage capacity upstream, and analyse strategic behaviour in a two-stage model. In this framework regulated storage tariffs – coupled with a centralized rationing mechanism – are compared with storage auctions. Finally, the authors consider the allocation of storage that arises from welfare maximization by a benevolent social planner. It was found that it is usually optimal to maximize the amount of storage capacity allocated to new entrants in liberalized gas markets. Storage auctions deviate from the optimal mechanism, but still afford greater efficiency than do rules that allocate storage capacity independently of its value. Furthermore, storage allocation appears to be a powerful mechanism with which to improve competition and efficiency in gas markets.

13/02021 Forecasting natural gas supply in China: production peak and import trends

Lin, B. and Wang, T. *Energy Policy*, 2012, 49, 225–233.
China's natural gas consumption has increased rapidly in recent years making China a net gas importer. As a non-renewable energy, the gas resource is exhaustible. Based on the forecast in this study, China's gas production peak is likely to approach in 2022. However, China is currently in the industrialization and urbanization stage, and its natural gas consumption will persistently increase. With China's gas production peak, China will have to face a massive expansion in gas imports. As the largest developing country, China's massive imports of gas will have an effect on the international gas market. In addition, as China's natural gas price is still controlled by the government and has remained at a low level, the massive imports of higher priced gas will exert great pressure on China's gas price reform.

13/02022 Gas-to-liquids (GTL): a review of an industry offering several routes for monetizing natural gas

Wood, D. A. *et al. Journal of Natural Gas Science and Engineering*, 2012, 9, 196–208.
Gas-to-liquids (GTL) has emerged as a commercially viable industry over the past 30 years offering market diversification to remote natural gas resource holders. Several technologies are now available through a series of patented processes to provide liquid products that can be more easily transported than natural gas, and directed into high value transportation fuel and other petroleum product and petrochemical markets. Recent low natural gas prices prevailing in North America are stimulating interest in GTL as a means to better monetize isolated shale gas resources. This article reviews the various GTL technologies, the commercial plants in operation, development and planning, and the range of market opportunities for GTL products. The Fischer–Tropsch (F–T) technologies dominate both large-scale and small-scale projects targeting middle distillate liquid transportation fuel markets. The large technology providers have followed strategies to scale-up plants over the past decade to provide commercial economies of scale, which to date have proved to be more costly than originally forecast. On the other hand, some small-scale technology providers are now targeting GTL at efforts to eliminate associated gas flaring in remote producing oil fields. Also, potential exists on various scales for GTL to supply liquid fuels in land-locked gas-rich regions. Technology routes from natural gas to gasoline via olefins are more complex and have so far proved difficult and costly to scale-up commercially. Producing dimethyl ether (DME) from coal and gas are growing markets in Asia, particularly China, Korea and Japan as LPG substitutes, and plans to scale-up one-step process technologies avoiding methanol production could see an expansion of DME supply chains. The GTL industry faces a number of challenges and risks, including: high capital costs; efficiency and reliability of complex process sequences; volatile natural gas, crude oil and petroleum product markets; integration of upstream and downstream projects; access to technology. This review article considers the GTL industry in the context of available opportunities and the challenges faced by project developers.

13/02023 Have oil and gas prices got separated?

Erdos, P. *Energy Policy*, 2012, 49, 707–718.

This paper applies vector error correction models that show that oil and natural gas prices decoupled around 2009. Before 2009, US and UK gas prices had a long-term equilibrium with crude prices to which gas prices always reverted after exogenous shocks. Both US and UK gas prices adjusted to the crude oil price individually, and departure from the equilibrium gas price on one continent resulted in a similar departure on the other. After an exogenous shock, the adjustment between US and UK gas prices took approximately 20 weeks on average, and the convergence was mediated mainly by crude oil with a necessary condition that arbitrage across the Atlantic was possible. After 2009, however, the UK gas price has remained integrated with oil price, but the US gas price decoupled from crude oil price and the European gas price, as the Atlantic arbitrage has halted. The oversupply from shale gas production has not been mitigated by North American export, as there has been no liquefying and export capacity.

13/02024 Increasing efficiency through market-based cross-border procurement of gas-balancing services in Europe

Keyaerts, N. and D'haeseleer, W. *Energy*, 2012, 47, (1), 564–576.

The gas-balancing mechanism makes up the interface between the users of the network and the transmission-system operator. The latter is responsible for the reliable and efficient operation of the network, whereas the former actually cause imbalances in the system. To deal with these imbalances the operator needs flexibility that can be offered by the network through line-pack flexibility or has to be procured from flexibility providers. Current procurement mechanisms often concern long-term and non-market-based agreements for domestically produced flexibility, likely leading to inefficiencies and raising barriers for entrants in the flexibility market. Market-based procurement of balancing services, on the other hand, relies on bids, specifying amount and price, submitted by all providers of flexibility and these bids, then, form a merit order from which the system operator can call the required amount of flexibility at the most efficient cost. Moreover, cross-border procurement of flexible gas enlarges the pool of flexibility providers and, as is demonstrated for hypothetical gas systems in two geographically adjacent regions, increases overall efficiency of the combined operators. Efficiency gains, however, are not distributed equally among the regions. Furthermore, border capacity should be strengthened when necessary because gas is pipeline-bound and trade cannot exceed available capacity.

13/02025 Introduction and advancement of a new clean global fuel: the status of DME developments in China and beyond

Fleisch, T. H. *et al. Journal of Natural Gas Science and Engineering*, 2012, 9, 94–107.

The past two decades saw the emergence of a new multi-source, multi-market fuel, dimethyl ether (DME). Prior to 1990, DME had only found limited commercial use as an aerosol propellant along with propane and butane as a green replacement for the chlorofluorohydrocarbons which were outlawed because of their detrimental impact on the ozone layer. DME is an environmentally benign, non-toxic, biodegradable product with physical properties similar to LPG. Global DME annual production capacity is approximately 10 million metric tons and actual market use is reported to be about 3 million metric tons – a remarkable increase from the 200,000 metric tons market demand in the early 2000s. Nearly all of the DME is produced in China from coal-derived methanol via the well-known catalytic dehydration process where two molecules of methanol react to form one molecule of DME and one molecule of water. DME is the fastest-growing methanol derivative, yet is still an emerging business with lots of upside opportunities combined with significant challenges. A number of other DME plants are in different stages of development around the world including Egypt, Middle East and Indonesia, all of them natural gas based. Sweden is the leader in the development of bio-DME produced through the gasification and conversion of black liquor, a by-product in Sweden's paper and pulp industry. Nearly all of today's DME is used as a blend stock for LPG which in turn is primarily used for cooking and heating. At blending levels below 20 vol%, the existing LPG blending facilities, local distribution infrastructure and end-use equipment can be used with minimal (if any) modifications – making for easy marketing. Currently, efforts are underway to commercialize DME as a high-quality diesel alternative. Technical issues such as new fuel injection systems and new fuel additives have been solved and solutions are currently being tested in fleets. This review will describe the history, status and future of DME as a global fuel alternative and how it has and will be changing the global methanol industry.

13/02026 Measuring vulnerability to shocks in the gas market in South America

Reymond, M. *Energy Policy*, 2012, 48, 754–761.

With a strong global demand for some 30 years, natural gas is a particular challenge for countries of South and Central America since each cubic meter of natural gas that is consumed is produced in this continent. It therefore seems appropriate to consider the risk of a collision gas and its effects on the countries most dependent on gas (either as producers or as consumers). This paper studies the vulnerability of gas in several countries on four ratios developed by in an earlier study. Once calculated from empirical data, these ratios helped to determine indicators and to classify countries according to their vulnerability in the event of a gas shock (sudden rise in prices). At a time of globalization and regional rapprochement, at present there is no homogeneity in the strategic and political choices of South American countries. On these points, it would seem that the option selected by some countries is the opposite of what happens in Europe (deintegration of historical monopolies, liberalization of the energy sector). Venezuela, for example, has opted for co-operation rather than competition by launching the creation of regional initiatives in the Caribbean (Petrocaribe) and with the countries from South America (Petrosur). The objective was to develop Venezuelan oil with collective investments and a preferential price for partner countries in return. As noted by Cabalu in an earlier study, in order to reduce global dependency on gas, governments can also try to improve the efficiency of the gas industry: upstream with the support of technologies facilitating gas exploration and production; and downstream with research and the development of new technologies which reduce gas consumption and increase the effectiveness of gas usage.

13/02027 Oil price shocks and trade imbalances

Le, T.-H. and Chang, Y. *Energy Economics*, 2013, 36, 78–96.

This study aims to examine whether a large part of the variability of trade balances and their oil and non-oil components is associated with oil price fluctuations. The long-run causality running from oil price to overall, oil and non-oil trade balances and their short-run dynamics are investigated by applying the Toda and Yamamoto 1995 causality approach and generalized impulse response functions, respectively to the monthly data spanning from January 1999 to November 2011. Three Asian economies that represent three distinct characteristics in terms of oil are chosen and examined: Malaysia as an oil exporter, Singapore as an oil refinery and Japan as an oil importer. The findings from the stability analysis lead to the following conclusions. First, relationships between oil price shocks and overall trade balances as well as between oil price shocks and trade components (oil and non-oil) vary considerably from year to year, in terms of sign, magnitude and the signal of causality. This is because of the different natures of oil price shocks. That is, depending on whether oil price shocks are caused by the demand side or supply side, responses of trade balances and their oil and non-oil components are expected to be different. Thus, conclusions based on all years combined would be misleading. Second, the findings of this study have critical implications for economic modelling of how oil price shocks impact a macroeconomy. The first implication is that trade is an important channel and thus should not be ignored in the model setup. The second one is that in modelling how oil price shocks impact the trade balance including its oil and non-oil components of an economy, it is of crucial importance to distinguish the nature of the economy such as an oil-exporting, oil-refinery and oil importing economy, and what are the causes of the shock, i.e. whether it is driven by the demand side or supply side.

13/02028 Techno-economic assessment and policy of gas power generation considering the role of multiple stakeholders in China

Dong, J. *et al. Energy Policy*, 2012, 48, 209–221.

In accordance with the energy planning in China, within the twelfth Five-Year Plan (2011–2015), the proportion of natural gas among primary energy consumption is expected to increase from the current 4% to 8%. In 2015, about 17 natural gas pipelines will be completed. This paper reviews the current situation of gas power generation, analyses the main opportunities and obstacles of gas power generation development in China, and conducts a techno-economic assessment of the natural gas power generation, taking into account the role and the interaction of the multiple stakeholders in the natural gas industry chain. Taking a power plant fuelled with the natural gas transported by the second west-to-east Pipeline as an example, it is found that the on-grid power price fluctuates upward with the rise of gas price and downward with the increase of annual utilization hours, and the influences of tax policies on the on-grid power price prove to be highly significant. As the analysis and calculation indicate, the environmental benefits of natural gas power generation ought to be strongly emphasized, compared with coal-fired power generation. In accordance with the results of the feasibility analysis and environmental impact analysis, this paper suggests that the multiple stakeholders in the gas industry chain should cooperate closely and the preferential policies should be set up to remove the obstacles restraining the gas power generation development. The policy recommendations include embedding environment benefits and peak regulation service value into the electricity price of gas power plants, adopting preferential tax policy, providing gas transportation and distribution fee discount, and signing more flexible gas trading contracts and so on. This sets forth an indisputable fact that the central government, the local government, national level gas company in charge of gas import and transmission, the local gas suppliers, the gas power plants, the grid company and end-users should strengthen the mutual coordination and make relevant contribution, respectively so as to promote healthy and sustainable development of the gas and electricity industry. The findings may provide decision support for the development of clean electricity industry and the implementation of national energy strategies in China, promote the market reform progress, and based on the mature market mechanism and effective regulation figure out the solutions to the existing problems.

Derived gaseous fuels

13/02029 Catalytic gasification of a Powder River Basin coal

Popa, T. *et al. Fuel*, 2013, 103, 161–170.

Catalytic gasification of a Wyodak low-sulfur sub-bituminous coal from the Powder River Basin of Wyoming was investigated using an inexpensive catalyst, Na_2CO_3, widely available in Wyoming. Experiments were performed in an atmospheric pressure fixed-bed laboratory gasifier. The effects of different factors including feed gas composition, catalyst loading and reaction temperature on the associated coal pyrolysis and char gasification were evaluated. Na_2CO_3 was found to be active during both pyrolysis and gasification steps and it can considerably decrease the activation energy of gasification step. The optimal Na_2CO_3 addition level is approximately 3 wt%. Shrinking core model and random pore model can be used to fit the kinetic data obtained under both non-catalytic and catalytic conditions.

13/02030 Catalytic upgrading nitrogen-riched wood syngas to liquid hydrocarbon mixture over a Fe–Pd/ZSM-5 catalyst

Yan, Q. *et al. Biomass and Bioenergy*, 2012, 47, 469–473.

Biomass like wood chips, switchgrass and other plant residues are first converted to syngas through gasification process using air, oxygen or steam. A downdraft gasifier is performed for syngas production in Mississippi state. The syngas from the gasifier contains up to 49% (vol.) N_2. High-level nitrogen-containing (nitrogen can be up to 60%) synthesis gas is converted to liquid hydrocarbon mixture through a one-stage catalytic process with a Fe–Pd/ZSM-5 catalyst. The Fe–Pd/ZSM-5 catalyst shows relatively high activity and selectivity in producing liquid hydrocarbons when running with nitrogen-rich syngas. The CO conversion, hydrocarbon selectivity and hydrocarbon distribution as a function of temperature, pressure, GHSV, composition of the feed, and reaction time are examined.

13/02031 Coproduction of clean syngas and iron from woody biomass and natural goethite ore

Kudo, S. *et al. Fuel*, 2013, 103, 64–72.

Conversion of biomass into clean syngas was studied considering application of low-grade iron ore to reforming of tar. Chipped cedar with moisture content of 0.1–10.1 wt% was continuously pyrolysed at 550 °C, and the nascent volatiles were subjected to reforming at 690–800 °C in a bed of mesoporous hematite derived from a type of natural goethite. The yield of heavy tar (b.p. > 350 °C) decreased from 18.8 to less than 0.01 wt% during the reforming mainly by its oxidation by the ore and conversion into coke. The hematite was reduced completely to magnetite and further but incompletely to wustite. The formation of iron was inhibited by high CO_2/CO and H_2O/H_2 ratios of the gas phase. The coke-loaded magnetite/wustite mixture was, however, an excellent precursor of iron. Reheating the spent ore up to 800 °C in the absence of the volatiles reduced the magnetite/wustite to wustite/iron obeying direct and indirect reduction mechanisms. Repeated cycles of such reheating and reforming converted the volatiles and ore into syngas with a total tar concentration as low as 10 mg N m^{-3}-dry and coke-loaded iron, respectively. Contribution of the steam reforming with iron–wustite redox cycles became more important as the reforming-reheating cycles were repeated.

13/02032 Effect of syngas composition on hydrogen permeation through a Pd–Ag membrane

Pinto, F. *et al. Fuel*, 2013, 103, 444–453.

Hydrogen separation from a syngas mixture with different compositions was studied by using a Pd–Ag membrane. The effect of temperature (from 300 to 600 °C) and of relative pressure (from 0.2 to 0.5 MPa) was studied. In general, rises of both these parameters allowed increasing H_2 permeate flux. The Pd–Ag membrane showed to have a great selectivity, as when inlet gas mixture contained different compositions of CO_2, CO or CH_4, these gases were never detected in membrane permeate side. However, when hydrogen content in inlet gas decreased, a significant reduction in H_2 permeate flux was observed, especially when CO was present, probably due to the deposition of solid carbon in membrane surface by Boudouard reaction. It was also observed the formation of hydrocarbons, due to CO and H_2 reactions. H_2 permeances were calculated by application of Sieverts' law and values between 4.9×10^{-4} and 1.5×10^{-3} mol m−2 s^{-1} $Pa^{-0.5}$ were obtained. The highest value was obtained at 600 °C. H_2 permeances at different temperature followed Arrhenius' equation. Thus, activation energies values between 11.5 and 14.0 kJ mol^{-1} were calculated.

13/02033 Experimental investigation of hydrogen production through heavy naphtha cracking in pulsed DBD reactor

Taghvaei, H. *et al. Applied Energy*, 2012, 98, 3–10.

Cracking of heavy naphtha is studied experimentally in a nanosecond pulsed dielectric barrier discharge (DBD) plasma reactor. The system has been evaluated for instant production of light gaseous hydrocarbons in the range of C_1–C_3 and hydrogen via continuous hydrocarbons cracking at room temperature and atmospheric pressure. The effect of some process parameters such as reactor geometry/gap distance, carrier gas and feed flow rates have been considered on the reactor performance, experimentally. Results indicate that the less carrier gas and feed flow rates cause more energy efficiency. The maximum process efficiency is found for carrier gas and feed flow rates of 50 and 1 ml/min, respectively, which gets higher to 106.23 l/kWh for 11.50 W input power and 1.35 mm inner electrode diameter. Furthermore, results proof that for cracking process in DBD reactors there is an optimum diameter to maximize the process efficiency. For the reactor studied here, the optimum diameter of inner electrode is 2.68 mm. In this case energy efficiency of the process is 159.29 l/kWh. Results indicates that the hydrocarbon product distribution during the process is $C_2 > C_1 \gg C_3 > C_4$.

13/02034 Highly stable and regenerable Mn-based/SBA-15 sorbents for desulfurization of hot coal gas

Zhang, F. M. *et al. Journal of Hazardous Materials*, 2012, 233–234, 219–227.

A series of mesoporous xCuyMn/SBA-15 sorbents with different Cu/Mn atomic ratios were prepared by wet impregnation method and their desulfurization performance in hot coal gas was investigated in a fixed-bed quartz reactor in the range of 700–850 °C. The successive nine desulfurization–regeneration cycles at 800 °C revealed that 1Cu9Mn/SBA-15 presented high performance with durable regeneration ability due to the high dispersion of Mn_2O_3 particles incorporated with a certain amount of copper oxides. The breakthrough sulfur capacity of 1Cu9Mn/SBA-15 observed 800 °C is 13.8 g S/100 g sorbents, which is remarkably higher than these of 40 wt%$LaFeO_3$/SBA-15 (4.8 g S/100 g sorbents) and 50 wt%$LaFe_2O_x$/MCM-41 (5.58 g S/100 g sorbents) used only at 500–550 °C. This suggested that the loading of Mn_2O_3 active species with high thermal stability to SBA-15 support significantly increased sulfur capacity at relatively higher sulfidation temperature. The fresh and used xCuyMn/SBA-15 sorbents were characterized by means of BET, XRD, XPS, XAES, TG/DSC and HRTEM techniques, confirmed that the structure of the sorbents remained intact before and after hot coal gas desulfurization.

13/02035 Methane production from solid-state anaerobic digestion of lignocellulosic biomass

Liew, L. N. *et al. Biomass and Bioenergy*, 2012, 46, 125–132.

Four lignocellulosic biomass feedstocks including corn stover, wheat straw, yard waste and leaves were evaluated for methane production via solid-state anaerobic digestion (SS-AD). Results showed that the highest methane yield was attained for corn stover (81.2 L kg^{-1} volatile solids (VS)), followed by wheat straw (66.9 L kg^{-1} VS), leaves (55.4 L kg^{-1} VS) and yard waste (40.8 L kg^{-1} VS) at a substrate to inoculum (S/I) ratio of 2. The methane production during SS-AD of tested lignocellulosic biomass followed the first-order kinetics model with correlation coefficients (r^2) of 0.91–0.98. The main contributor to methane production during SS-AD of corn stover and wheat straw was the degradation of cellulose and hemicellulose while the degradation of extractives was more predominant in yard waste and leaves. An inverse linear relationship was obtained between the methane yield and the lignin content and a positive linear relationship was found between the methane yield and the enzymatic digestibility of the lignocellulosic biomass.

13/02036 Numerical investigation of the effects of fuel variability on the dynamics of syngas impinging jet flames

Martinez, D. M. *et al. Fuel*, 2013, 103, 646–662.

Numerical simulations using the large-eddy simulation technique is presented to study the effects of fuel variability on the dynamics of hydrogen and syngas impinging flames. The compositions of CO and H_2 are varied in a syngas mixture, including a pure H_2 case as the baseline case 1, 20% CO with 80% H_2 for case 2, 40% CO with 60% H_2 for case 3, and 20% CO with 20% CO_2 and 60% H_2 for case 4. The impinging flame configuration has a distance to nozzle diameter ratio of $H/d = 20$ and the inlet velocity of the fuel is 27 m/s. The fuel is issued from a circular nozzle and mixes with air in a non-premixed configuration. The results show that the flames develop vortical structures in the primary jet associated with the buoyancy and shear layer instability, and the wall jet progresses parallel to the impinging plate forming large-scale vortex rings at different locations and strengths as a consequence of the fuel compositions. A comprehensive analysis of vortical structures in the primary and secondary jet streams, along with a description of their effects on the near-wall heat transfer and instabilities of syngas flames is presented here. Pollutant emissions and species formations are also investigated in order to gain further insight into the syngas burning characteristics for future cleaner combustion systems.

13/02037 Simultaneous removal of hydrogen sulfide and mercury from simulated syngas by iron-based sorbents

Wang, J. *et al. Fuel*, 2013, 103, 73–79.

Two iron oxide based sorbents, TG-1 and TG-F, with high desulfurization efficiency, were selected for simultaneous removal of H_2S and Hg from simulated syngas. The evaluation tests were carried out using a fixed bed reactor at different temperatures and in ambient atmosphere. The different activities for the simultaneous removal of H_2S and Hg between TG-1 and TG-F or TG-1-S (denoted as such after uptake of H_2S) were compared. The results show that the two iron oxide based sorbents can capture Hg effectively from simulated syngas. The preferred temperature for Hg removal using the TG-F and TG-1 sorbents are 60–120 and 100–140 °C, respectively. The Hg absorption capacity of TG-1 is higher than that of TG-F under the same conditions. CO and H_2 in the feed gas have negligible effect on the efficiency of Hg removal. H_2S is favoured for the removal of Hg over iron-based sorbents and it was found that the influence of H_2S concentration on the Hg capacity of the TG-1 and TG-F sorbents are different. It is found that the main active components of the two sorbents during the reaction are different. After several desulfurization cycles, the TG-1-S sorbent has a high efficiency for Hg removal from the simulated syngas.

13/02038 Solid-state co-digestion of expired dog food and corn stover for methane production

Xu, F. and Li, Y. *Bioresource Technology*, 2012, 118, 219–226.

Expired dog food was co-digested with corn stover for biogas production via solid-state anaerobic digestion (SS-AD) at feedstock-to-effluent (F/E) ratios of 2, 4, and 6 using effluent from a sewage sludge digester as inoculum. Degradation of the main components in dog food and corn stover was measured. Higher methane yields were obtained at lower F/E ratios and at higher percentages of dog food in the substrate. The highest methane yield of 304.4 L/kg VS_{feed} was obtained for the substrate containing 50% corn stover and 50% dog food, which was an increase of 229% and 109% compared to digesting corn stover and dog food alone, respectively. Co-digestion of corn stover with dog food reduced the start-up time and volatile fatty acid (VFA) accumulation, but decreased the cellulose and xylan degradation of corn stover.

13/02039 Syngas production from gasification of brown coal in a microwave torch plasma

Hong, Y. C. *et al. Energy*, 2012, 47, (1), 36–40.

Atmospheric-pressure pure steam torch plasma was generated by making use of 2.45 GHz microwave energy and was used in a coal gasification investigation. The steam torch plasma contains also highly active species, enhancing the chemical reaction rate and eliminating the need for catalysts in material processing. Fine coal powders with an average particle size of 70 μm were delivered through a feeder and used in the experiment. The brown coal from Indonesia with ash and moisture content of 38.12% was injected to the steam torch with microwave power of 4 kW. From the experimental data showing the relative concentrations of synthesized gas species versus the ratio of coal to steam for brown coal at the microwave power of 4 kW, the relative concentrations of synthesized gases at a ratio of 1.36 of coal to steam was 48% of hydrogen, 23% of carbon monoxide, 25% of carbon dioxide and 4% of methane. The further increase of coal to steam ratio did not much reduce carbon dioxide concentration. A low-grade coal can also be well gasified in steam plasma torch.

13/02040 Synthesis gas production from catalytic gasification of waste biomass using nickel-loaded brown coal char

Xiao, X. *et al. Fuel*, 2013, 103, 135–140.

This paper presents an experimental research concerning the catalytic gasification of waste biomass to synthesis gas using Ni-loaded brown coal char (Ni/BCC). The attention is focused on the catalytic conditions for enhancing the synthesis gas production, improving its composition and extending the catalyst lifetime. The aim is achieved by means of the characterization of Ni/BCC and the product gas analysis, through gasification experiments of a woody biomass and an animal-waste-derived biomass both in a fixed bed reactor and a fluidized bed reactor at various catalytic temperatures and steam/biomass–carbon (S/C) ratios. Effects of the pyrolysis temperature and the steam treatment on the nickel crystallite size are analysed and used as the reference of choosing optimum gasification conditions. With brown coal char as support material, Ni/BCC is found as an excellent catalyst even at low temperature of about 650 °C and shows a good resistance ability of coke formation, compared to non-catalyst and Ni/Al_2O_3. More than 25 h continuous operation is also performed in a 1 kg/h internally circulating fluidized-bed gasifier (ICFG) to assess the lifetime of Ni/BCC. Smaller S/C ratio at the appropriate temperature is suggested to lower the coal char gasification, thereby reducing the degradation of the support material.

13/02041 Thermodynamic equilibrium analysis of coal gasification using Gibbs energy minimization method

Shabbar, S. and Janajreh, I. *Energy Conversion and Management*, 2013, 65, 755–763.

A thermodynamics analysis of gasification process is performed using the Gibbs energy minimization approach through Lagrange multiplier method. Three different methods of gasification are analysed to convert bituminous (RTC) coal into syngas (CO and H_2). These methods use air, air-steam and solar-steam, respectively, for gasification. Initially the properties of coal are experimentally determined using bomb calorimeter, simultaneous DSC/TGA Q600 thermal analyser and Flash 2000 (CHNO-S) analyser to measure higher heating value, proximate and ultimate composition, respectively. Using the experimental data an empirical formula of coal is derived to formulate a gasification model. The model accounts 44 species in the product that also includes for the solid carbon and sulfur. The result of gasification model is presented in terms of equilibrium composition of product gases with the inclusion of minor. In the end, the cold gasification efficiency is calculated that shows the efficiency of 70.94%, 71.64% and 90.67% for air, air-steam and solar-steam gasification, respectively. The cold gasification efficiency clearly shows an added efficiency for solar-steam gasification process.

LNG

13/02042 A review and outlook for the global LNG trade

Wood, D. A. *Journal of Natural Gas Science and Engineering*, 2012, 9, 16–27.

The evolution of global and regional liquefied natural gas (LNG) trade over the past 20 years has been a story of rapid growth, diversification and increased flexibility in LNG cargo movements. Asia continues to dominate global LNG trade, but the European LNG market has evolved significantly in the past decade and seems destined for sustained growth and diversification over the next decade or so. Despite the LNG import market in North America being overwhelmed by unconventional gas developments in the past few years, future sustained growth of LNG demand in Asia and Europe are underpinned by firm new project commitments. A number of North American LNG export projects are progressing with a view to supplying this growing market demand in Europe and Asia. New gas discoveries in deep-water offshore East Africa and Eastern Mediterranean are also likely to compete for LNG market share in growing European and Asian gas markets Country and regional statistics presented illustrate how significantly the global LNG industry has changed in the past decade. These statistics reveal the complexity of commercial, political and technical drivers at play, particularly in the case of Europe, and how these drivers are conspiring to boost future demand for LNG.

13/02043 Consensual decision-making model based on game theory for LNG processes

Castillo, L. and Dorao, C. A. *Energy Conversion and Management*, 2012, 64, 387–396.

Decision-making (DM) in liquefied natural gas (LNG) projects is a quite complex process due to the number of actors, approval phases, large investments and capital return in the long time. Furthermore, due to the very high investment of a LNG project, a detailed and efficient DM process is required in order to minimize risks. In this study a DM approach for LNG projects is presented. The approach is based on a consensus algorithm to address the consensus output over a common value using cost functions within a framework based on game theory. The DM framework was tested with two different cases. The first case was used for evaluating the performance of the framework with analytical models, while the second case corresponds to a simple LNG process. The problems were solved by using a genetic algorithm (GA) binary coding and Nash-GA. The results of the DM framework in the LNG project indicate that considering an integrated DM model and including the markets role from the design and optimization of the process more realistic outcome could be obtained. However, the major challenge in such a framework is related to the uncertainties in the market models.

13/02044 Enhancement of LNG plant propane cycle through waste heat powered absorption cooling

Rodgers, P. *et al. Applied Thermal Engineering*, 2012, 48, 41–53.

In liquefied natural gas (LNG) plants utilizing sea water for process cooling, both the efficiency and production capacity of the propane cycle decrease with increasing sea water temperature. To address this issue, several propane cycle enhancement approaches are investigated in this study, which require minimal modification of the existing plant configuration. These approaches rely on the use of gas turbine waste heat powered water/lithium bromide absorption cooling to either (i) subcool propane after the propane cycle condenser or (ii) reduce propane cycle condensing pressure through pre-cooling of condenser cooling water. In the second approach, two alternative methods of pre-cooling condenser cooling water are considered, which consist of an open sea water loop, and a closed fresh water loop. In addition for all cases, three candidate absorption chiller configurations are evaluated, namely single-effect, double-effect, and cascaded double- and single-effect chillers. The thermodynamic performance of each propane cycle enhancement scheme, integrated in an actual LNG plant in the Persian Gulf, is evaluated using actual plant operating data. Subcooling propane after the propane cycle condenser is found to improve propane cycle total coefficient of performance (COP_T) and cooling capacity by 13% and 23%, respectively. The necessary cooling load could be provided by either a single-effect, double-effect or cascaded and single- and double-effect absorption refrigeration cycle recovering waste heat from a single gas turbine operated at full load. Reducing propane condensing pressure using a closed fresh water condenser cooling loop is found result in propane cycle COP_T and cooling capacity enhancements of 63% and 22%, respectively, but would require substantially higher capital investment than for propane subcooling, due to higher cooling load and thus higher waste heat requirements. Considering the present trend of short process enhancement payback periods in the natural gas industry, subcooling propane after the propane cycle condenser is recommended as the preferred option to boost propane cycle performance.

13/02045 Hydrodynamic interaction between FLNG vessel and LNG carrier in side by side configuration

Zhao, W.-h. *et al. Journal of Hydrodynamics, Ser. B*, 2012, 24, (5), 648–657.

The floating liquefied natural gas (FLNG) is a new type of floating platform for the exploitation of stranded offshore oil/gas fields. The side by side configuration for the FLNG vessel and the LNG carrier arranged in parallel is one of the possible choices for the LNG offloading. During the offloading operations, the multiple floating bodies would have very complex responses due to their hydrodynamic interactions. In this study, numerical simulations of multiple floating bodies in close proximity in the side by side offloading configuration are carried out with the time domain coupled analysis code SIMO. Hydrodynamic interactions between the floating bodies and the mechanical coupling effects between the floating bodies and their connection systems are included in the coupled analysis model. To clarify the hydrodynamic effects of the two vessels, numerical simulations under the same environmental condition are also conducted without considering the hydrodynamic interactions, for comparison. It is shown that the hydrodynamic interactions play an important role in the low frequency motion responses of the two vessels, but have little effect on the wave frequency motion responses. In addition, the comparison results also show that the hydrodynamic interactions can affect the loads on the connection systems.

13/02046 In-situ stress and fault reactivation associated with LNG injection in the Tiechanshan gas field, fold-thrust belt of Western Taiwan

Hung, J.-h. and Wu, J.-c. *Journal of Petroleum Science and Engineering*, 2012, 96–97, 37–48.

The Tiechanshan gas field located in the fold-thrust belt of western Taiwan was depleted and converted for underground storage of liquefied natural gas (LNG) decades ago. Recently, CO_2 sequestration has been planned at shallower depths of this structure. This study characterizes the *in situ* stresses from over 40 wells and assess the leakage potential through fault reactivation in response to LNG-injection increased pore-pressure. The formation pore pressure (P_f), vertical stress (S_v), and minimum horizontal stress (S_{hmin}) are measured from repeated formation tests, density logs, and hydrofrac data including leak-off tests and fluid injection. Formation pore pressures are hydrostatic above depths of 2 km, and increase with local gradients of 14.02 and 21.26 MPa/km above and below 3.2 km, respectively. Extremely high pore pressures ($\lambda p = 0.8$) are observed at depths below 3.8 km. Lower than normal pressures (average 9.47 MPa/km) are observed in the gas-bearing reservoir of the Talu A-sand. The gradient of S_{hmin} is ~17.46 MPa/km or equivalent to 0.74 of S_v (~23.60 MPa/km). A detailed structure contour map of the top of the A-sand, combined with the measured S_{hmin} and S_v, show that the stress state in the Tiechanshan field is predominantly strike-slip stress regime ($S_{Hmax} > S_V > S_{hmin}$). An upper-bound value of the maximum horizontal stress (S_{Hmax}) constrained by frictional limits and the coefficient of friction ($\mu = 0.6$) is about 27.36 MPa/km. Caliper logs from two wells show that the mean azimuth of preferred orientation of borehole breakouts are in ~028°N. Consequently, the maximum horizontal stress axis tends 118°N, which is sub-parallel to the far-field plate-convergence direction. Geomechanical analyses of the reactivation of pre-existing faults at the depths of the LNG reservoir sand indicate that all faults are stable at the present stress state. Sensitivity analyses indicate that ~5.9 MPa excess pore pressure would be required to cause the optimal oriented f1 fault to reactivate. This corresponds to LNG column heights of ~760 m (density = ~790 kg/m^3), whereas the height of structural closure of the A-sand does not exceed 400 m. Therefore, it is unlikely that LNG injection will reactivate f1 fault.

13/02047 On the conceptual design of pre-cooling stage of LNG plants using propane or an ethane/propane mixture

Castillo, L. and Dorao, C. A. *Energy Conversion and Management*, 2013, 65, 140–146.

Today, liquefied natural gas (LNG) technologies are based on pure and mixed refrigerants cycles on the pre-cooling system, but the advantages and disadvantages of considering a mixed refrigerant or pure refrigerant cycle in the pre-cooling stage is not well understood. In this work an analysis of the compressors and the refrigerants in the pre-cooling system is carried out. The most relevant aspect of the evaluation is to establish some thermodynamical criteria for the selecting of the suitable refrigerant for the pre-cooling stage. For final decision-making process of the selection of the pre-cooling stage, a proper model is required which should take into account all aspects that could affect the capital and operation costs.

Hydrogen generation and storage

13/02048 2D heat and mass transfer modeling of methane steam reforming for hydrogen production in a compact reformer

Ni, M. *et al. Energy Conversion and Management*, 2013, 65, 155–163.

Compact reformers (CRs) are promising devices for efficient fuel processing. In CRs, a thin solid plate is sandwiched between two catalyst layers to enable efficient heat transfer from combustion duct to the reforming duct for fuel processing. In this study, a two-dimensional (2D) heat and mass transfer model is developed to investigate the fundamental transport phenomenon and chemical reaction kinetics in a CR for hydrogen production by methane steam reforming (MSR). Both MSR reaction and water gas shift reaction (WGSR) are considered in the numerical model. Parametric simulations are performed to examine the effects of various structural/operating parameters, such as pore size, permeability, gas velocity, temperature, and rate of heat supply on the reformer performance. It is found that the reaction rates of MSR and WGSR are the highest at the inlet but decrease significantly along the reformer. Increasing the operating temperature raises the reaction rates at the inlet but shows very small influence in the downstream. For comparison, increasing the rate of heat supply raises the reaction rates in the downstream due to increased temperature. A high gas velocity and permeability facilitates gas transport in the porous structure thus enhances reaction rates in the downstream of the reformer.

13/02049 Design of new strategy for green algal photo-hydrogen production: spectral-selective photosystem I activation and photosystem II deactivation

Hoshino, T. *et al. Bioresource Technology*, 2012, 120, 233–240.

A new strategy in photosynthetic hydrogen (photo-H_2) production from green algae was developed based on theory and successfully demonstrated. The new strategy applied a spectral-selective photosystem I (PSI) activating/photosystem II (PSII) deactivating radiation (or PSI light) that would drive a steady flow of electrons in the electron transport chain for delivery to hydrogenase for photo-H_2 production, but would reduce oxygen production through water photolysis below the respiratory oxygen consumption so that an anoxic condition would be maintained as required by hydrogenase. Implementing the strategy by using a PSI light (692 nm peak, 680–700 nm) on *Chlamydomonas reinhardtii* cells resulted in relatively sustained photo-H_2 production (total of $0.108\,mL\,H_2\,mg^{-1}$ Chl, exceeding $0.066\,mL\,H_2\,mg^{-1}$ Chl under white light). The strategy also proved successful and convenient in allowing cells to alternately switch between photo-H_2 production and a recovery period by simply turning on or off the PSI light.

13/02050 Electrochemical hydrogen storage in activated carbons with different pore structures derived from certain lignocellulose materials

Babel, K. *et al. Carbon*, 2012, 50, (14), 5017–5026.

Activated carbons exhibiting high hydrogen electrosorption were produced from selected precursors: coconut shells, blackthorn stones, cellulose and lignin. The influence of the carbonization condition and activation with KOH on their structural parameters and, hence, hydrogen electrosorption ability, was investigated. A positive effect of fast, aggressive activation was demonstrated for precursors subjected to initial carbonization at moderately high temperature (700 °C). The highest hydrogen electrosorption, allowing storage of electrical charge of 625 $\mathrm{mA\,h\,g^{-1}}$, an equivalent of hydrogen gas storage of 2.31 wt%, was obtained for blackthorn stones after 15 min activation at 950 °C and carbonizate/KOH ratio of 1/5. Further prolongation of the activation process is disadvantageous as it leads to the burn-off of the sample and the increase of the micropore diameter and, finally, reduction of hydrogen sorption ability. This loss cannot be fully compensated by the secondary pores created afterwards by the burn-off with K_2CO_3. The investigations confirmed that an efficient hydrogen electrosorption could be obtained by using active carbons made of cheap and easily available natural, plant-derived precursors, instead of special carbonaceous materials produced by complicated methods.

13/02051 Exergoeconomic analysis and performance assessment of hydrogen and power production using different gasification systems

Kalinci, Y. *et al. Fuel*, 2012, 102, 187–198.

This study investigates three different gasifiers for hydrogen production, namely, downdraft gasifier (DG), circulating fluidized bed gasifier (CFBG) and plasma gasifier (PG) as taken from the literature under cases 1–3, respectively. These cases are then modified for cogeneration of hydrogen and power. The authors use the specific exergy cost (SPECO) method to calculate exergy-related parameters and display cost flows for all streams and components. The case studies are selected from different countries. The authors study how flow rates of streams cost and hydrogen unit costs change if these facilities operate in Turkey. The process life time is considered 15 years, and the inflation rate and energy inflation rate are taken from the Central Bank of the Republic of Turkey as 8.91% and 19.25% while unit energy, water and biomass costs are taken 31.38 $/GJ, 4.59 $/t and 35.42 $/t for Turkey, respectively. The electric power requirements are calculated to be 0.0915, 12.53 and 23.26 $\mathrm{MW_e}$ for DG, CFBG and PG, respectively. In cases 1–3, the electric power generated by the systems are 0.144, 1.17 and 3.88 MW, respectively and may be sold to the national grid with cost rates of 31.8, 258.39 and 856.88 $/h. In the systems, the hydrogen production rates and costs per unit mass are obtained to be 0.004, 0.521 and 0.155 kg/s and 1.16, 3.33 and 2.45 $/kg for the DG, the CFBG and the PG, respectively.

13/02052 Hydrogen production by supercritical water gasification of glucose with Ni/CeO_2/Al_2O_3: effect of Ce loading

Lu, Y. *et al. Fuel*, 2013, 103, 193–199.

Ni-based SCWG catalysts attract more attention for its high activity and relatively low cost. However, carbon deposition, which is one of the serious problems, reduces the activity of Ni-based catalysts. Ni/CeO_2/Al_2O_3 catalysts with different Ce loading were prepared by a wet impregnation method. The performance of catalyst in supercritical water was tested in an autoclave reactor at 673 K, 24.5 MPa. The catalysts before and after reaction were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), BET specific surface area measurements and thermogravimetric analyses (TGA). The effects of Ce loading in catalysts on glucose gasification were studied. The results showed that hydrogen yield and hydrogen selectivity increased sharply with addition of Ni/CeO_2/Al_2O_3 catalysts. When the Ce loading content was 8.46 wt%, the maximum H_2 yield and H_2 selectivity were obtained. The carbon deposition and coking will lead to the deactivation of the catalysts. Based on the TGA, the oxidant kinetic data of carbon deposited on the used catalysts with air was obtained. CeO_2 in the Ni/CeO_2/Al_2O_3 catalyst plays an important role in inhibiting carbon deposition by increasing the Ni dispersion and reacting with deposited carbon.

13/02053 Mathematical model for a continuous hydrogen production system: stirred fermenter connected to a biocatalyzed electrolysis cell

Blanco-Cocom, L. *et al. Biomass and Bioenergy*, 2013, 48, 90–99.

This paper presents a mathematical model applied to a continuous hydrogen production system, composed of a stirred fermenter connected to a biocatalysed electrolysis cell (BEC). The model contemplates two differential equation systems which describe the adaptation (start-up) and continuous phases between the fermenter and the BEC. The proposed model describes the dynamics of hydrogen and volatile fatty acid (VFA) production and substrate consumption (glucose for the stirred fermenter and acetate in the BEC), based on a Tessier-type bacterial kinetic which simulates the lag phase in the bacteria. A hybrid evolutionary algorithm and least squares method were used to estimate the parameters. Model validation and simulation were achieved by obtaining the volumes of hydrogen and VFAs produced and the statistical bacterial density via the most probable number method.

13/02054 Optimization geometries of a vortex gliding-arc reactor for partial oxidation of methane

Xu, G. and Ding, X. *Energy*, 2012, 47, (1), 333–339.

The effects of the geometry of gliding-arc reactor – such as distance between the electrodes, outlet diameter, and inlet position – on the reactor characteristics (methane conversion, hydrogen yield, and energy efficiency) have not been fully investigated. In this paper, AC gliding-arc reactors including the vortex flow configuration are designed to produce hydrogen from the methane by partial oxidation. The influence of vortex flow configuration on the reactor characteristics is also studied by varying the inlet position. When the inlet of the gliding-arc reactor is positioned close to the outlet, reverse vortex flow reactor (RVFR), the maximum energy efficiency reaches 50% and the yields of hydrogen and carbon monoxide are 40% and 65%, respectively. As the distance between electrodes increases from 5 to 15 mm, both hydrogen yield and energy efficiency increase approximately 10% for the RVFR. The energy efficiency and hydrogen yield are highest when the ratio of the outlet diameter to the inner diameter is 0.5 for the RVFR. Experimental results indicate that the flow field in the plasma reactor has an important influence on the reactor performance. Furthermore, hydrogen production increases as the number of feed gas flows in contact with the plasma zone increases.

13/02055 Particle swarm optimization based fuzzy logic controller for autonomous green power energy system with hydrogen storage

Safari, S. *et al. Energy Conversion and Management*, 2013, 65, 41–49.

The objective of this study is to develop an optimized fuzzy logic controller (FLC) for operating an autonomous hybrid green power system (HGPS) based on the particle swarm optimization (PSO) algorithm. An electrolyser produces hydrogen from surplus energy generated by the wind turbine and photovoltaic array of HGPS for later use by a fuel cell. The PSO algorithm is used to optimize membership functions of the FLC. The FLC inputs are (a) net power flow and (b) batteries state of charge (SOC) and FLC output determines the time for hydrogen production or consumption. Actual data for weekly residential load, wind speed, ambient temperature, and solar irradiation are used for performance simulation and analysis of the HGPS examined. The weekly operation and maintenance (O&M) costs and the loss of power supply probability (LPSP) are considered in the optimization procedure. It is determined that FLC optimization results in (a) reduced fluctuations in batteries SOC which translates into longer life for batteries and the average SOC is increased by 6.18% and (b) less working hours for fuel cell, when the load is met by wind and PV. It is found that the optimized FLC results in lower O&M costs and LPSP by 57% and 33%, respectively, as compared to its un-optimized counterpart. In addition, a reduction of 18% in investment cost is achievable by optimal sizing and reducing the capacity of HGPS equipment.

13/02056 Preparation of sulfur-doped microporous carbons for the storage of hydrogen and carbon dioxide

Xia, Y. *et al. Carbon*, 2012, 50, (15), 5543–5553.

Structurally well-ordered, sulfur-doped microporous carbon materials have been successfully prepared by a nanocasting method using zeolite EMC-2 as a hard template. The carbon materials exhibited well-resolved diffraction peaks in powder XRD patterns and ordered micropore channels in TEM images. Adjusting the synthesis conditions, carbons possess a tunable sulfur content in the range of 1.3–6.6 wt%, a surface area of 729–1627 $\mathrm{m^2\,g^{-1}}$ and a pore volume of 0.60–0.90 $\mathrm{cm^3\,g^{-1}}$. A significant proportion of the porosity in the carbons (up to 82% and 63% for surface area and pore volume, respectively) is contributed by micropores. The sulfur-doped microporous carbons exhibit isosteric heat of hydrogen adsorption up to 9.2 $\mathrm{kJ\,mol^{-1}}$ and a high hydrogen uptake density of 14.3×10^{-3} $\mathrm{mmol\,m^{-2}}$ at −196 °C and 20 bar, one of the highest ever observed for nanoporous carbons. They also show a high CO_2 adsorption energy up to 59 $\mathrm{kJ\,mol^{-1}}$ at lower coverages (with 22 $\mathrm{kJ\,mol^{-1}}$ at higher CO_2 coverages), the highest ever reported for any porous carbon materials and one of the highest amongst all the porous materials. These findings suggest that S-doped microporous carbons are potential promising adsorbents for hydrogen and CO_2.

13/02057 Process investigations of extreme thermophilic fermentations for hydrogen production: effect of bubble induction and reduced pressure

Sonnleitner, A. *et al. Bioresource Technology*, 2012, 118, 170–176.

Hydrogen production via thermophilic dark fermentation is considered a sustainable way to produce renewable hydrogen. For industrial scale an optimization of hydrogen production is of highest importance. The aim of this work was to evaluate induced bubble formation and applying reduced pressure as methods of removing produced hydrogen instead of external gas stripping. Evaluation was carried out in a continuously stirred tank reactor using the extremely thermophilic bacterium *Caldicellulosiruptor saccharolyticus*. The addition of a bubble formation inductor was able to maintain the fermentation, but only at low hydrogen production rates and yields. Applying reduced pressure at a level of 305 mbar, nitrogen stripping could be omitted and hydrogen yields of around 72% of the theoretical maximum were achieved. It was proven, that application of reduced pressure is a promising alternative to inert gas stripping to obtain high hydrogen productivities and yields for thermophilic dark fermentations.

13/02058 Technological challenges for industrial development of hydrogen production based on methane cracking

Abánades, A. *et al. Energy*, 2012, 46, (1), 359–363.

The world energy demand is foreseen to increase due to the improvements of the living standard in the developing countries and to the development of the global economy. The increase in sustainability of the energy supply must be considered as a must to avoid spoiling the natural resources, whose availability will be crucial for next generations. The CO_2-free utilization of available energy sources is one of the ways to attain such objectives. Innovative solutions should be put into practice for the CO_2-free exploitation of the huge fossil fuel resources already available. This study explores the possibility to enlarge the fossil fuel availability without CO_2 emissions by the analysis of the technological options to obtain Hydrogen as energy carrier from hydrocarbon decarburation, mainly methane. A brief analysis of those options and a discussion about their state-of-the-art will be done, to establish their potential and the R&D required to assess their practical implementation in a medium term.

04 BY-PRODUCTS RELATED TO FUELS

13/02059 Catalytic esterification of fatty acids using solid acid catalysts generated from biochar and activated carbon

Kastner, J. R. *et al. Catalysis Today*, 2012, 190, (1), 122–132.

Reusable, solid acid carbon supported catalysts were generated from biomass by pyrolysis (400–500 °C) to generate a soft to hard carbon backbone (i.e. biochar) for addition of acidic functional groups. Acid catalysts were synthesized by sulfonating the biochar and wood-derived activated carbon using concentrated H_2SO_4 at 100, 150 and 200 °C (12 h) and gaseous SO_3 (23 °C). Attenuated Total Reflectance, sulfur, and NH_3-TPD analysis of the sulfonated carbons indicated the presence of $-SO_3H$ groups on the 100 °C sulfonated biochar and activated carbon (AC), with higher active site densities (SO_3H density) for the SO_3 sulfonated material. The sulfonated carbons were tested for their ability to esterify free fatty acids with methanol in blends with vegetable oil and animal fat (5–15 wt% FFA). Esterification of the fatty acids was typically complete (~90–100% conversion) within 30–60 min at 55–60 °C (large methanol excess), but decreased with lower methanol to oil ratios using the biochar catalysts (e.g. 70%, 6 h, 20:1). Solid acid catalysts derived from wood based activated carbon had significantly higher activity compared to the biochar derived catalysts (e.g. 97%, 6 h, 6:1). Of the synthesized biochar catalysts, 400 °C pyrolysed pine chip biochar, sulfonated at 100 °C, resulted in the highest reaction rate and lowest reduction in conversion (or deactivation) when reused multiple times. Drying the biochar catalysts for 1 h at 125 °C between uses maintained esterification activity, allowing the catalysts to be reused up to seven cycles. For the SO_3 sulfonated AC catalyst, such a regeneration step was not required, as the fractional conversion of palmitic and stearic acid (5% FFA, 10:1, 3 h) remained >90% after six cycles.

13/02060 Chemical modification of coal fly ash for the retention of low levels of lead from aqueous solutions

Muñoz, M. I. and Aller, A. J. *Fuel*, 2012, 102, 135–144.

A chemically modified coal fly ash was prepared by immobilization of mercaptoethanol or mercaptoacetic acid to develop a low-cost and effective solid phase retention system for low levels of lead from aqueous solutions. The organically functionalized coal fly ash-based retention system experienced high thermal and chemical stability. The batch extraction procedure was used to explore the equilibrium, kinetic and thermodynamic characteristics of the retention of lead by the functionalized sorbent at various temperatures. Several equilibrium models were compared to evaluate the lead retention process with a better fitting using the Langmuir model. Kinetic studies were also carried out to fit the experimental data. The pseudo-second-order and Elovich models provided the highest coefficients of determination, but the function Z and the McLintock method confirmed better applicability of the Elovichian model. Lead was retained up to about $45\,\mu g\,g^{-1}$ at pH 5.0, with similar results for the two ligands, mercaptoethanol and mercaptoacetic acid. Thermodynamic studies provided negative free energy changes, indicating spontaneity of the retention process. Positive values for both enthalpy and entropy indicated an endothermic retention with high affinity lead–sorbent.

13/02061 Environmental hazard of oil shale combustion fly ash

Blinova, I. *et al. Journal of Hazardous Materials*, 2012, 229–230, 192–200.

The combined chemical and ecotoxicological characterization of oil shale combustion fly ash was performed. Ash was sampled from the most distant point of the ash-separation systems of the Balti and Eesti thermal power plants in north-eastern Estonia. The fly ash proved potentially hazardous for tested aquatic organisms and high alkalinity of the leachates (pH > 10) is apparently the key factor determining its toxicity. The leachates were not genotoxic in the Ames assay. Also, the analysis showed that despite long-term intensive oil-shale combustion accompanied by considerable fly ash emissions has not led to significant soil contamination by hazardous trace elements in north-eastern Estonia. Comparative study of the fly ash originating from the 'new' circulating fluidized bed (CFB) combustion technology and the 'old' pulverized-fired (PF) one showed that CFB fly ash was less toxic than PF fly ash. Thus, complete transfer to the 'new' technology will reduce (i) atmospheric emission of hazardous trace elements and (ii) fly ash toxicity to aquatic organisms as compared with the 'old' technology.

13/02062 High temperature thermal barrier coatings from recycled fly ash cenospheres

Arizmendi-Morquecho, A. *et al. Applied Thermal Engineering*, 2012, 48, 117–121.

The high temperature behaviour of electrophoretically deposited thermal barrier coatings based on recycled fly ash cenospheres is presented. Thermal properties such as thermal expansion coefficient, specific heat, thermal conductivity, thermal diffusivity and thermal effusivity of fly ash (FA) and fly-ash cenospheres (FAC) were measured in the temperature range of 373–1173 K. Thermal conductivity values as low as 0.17 and 0.32 W/m K for FAC and FA, respectively, at 1200 K were found. These results confirm their potentiality as ultra-low thermal conductivity thermal insulators for high temperature applications.

13/02063 Influence of nickel oxide on carbon dioxide adsorption behaviors of activated carbons

Jang, D.-I. and Park, S.-J. *Fuel*, 2012, 102, 439–444.

In this work, the adsorption behaviours of nickel oxide loaded activated carbons were studied in carbon dioxide capture. The nickel oxides were introduced on to the activated carbons using a post-oxidation method including nickel electrodeless plating at 573 K in an air stream. The structure of the nickel oxide loaded activated carbons was characterized by XRD. The nickel oxide contents on the activated carbons were verified by XPS, and the textural properties were analysed by N_2/77 K isotherms. The carbon dioxide adsorption behaviours of the nickel oxide loaded activated carbons were observed in the amounts of carbon dioxide adsorptions at 298 K and 1.0 atm. As the post-oxidation time increased, the carbon dioxide adsorption capacity was enhanced. From the results, it was found that the nickel oxide on the activated carbons led to an increase in the carbon dioxide adsorption capacity of the activated carbons.

13/02064 Mercury removal by bio-char based modified activated carbons

De, M. *et al. Fuel*, 2013, 103, 570–578.

This study investigated the effects of mercury concentration, process temperature, halides impregnating agents, halides precursor, and halides loading concentration on the mercury removal efficiency of the bio-char derived activated carbons from gaseous phase. The mercury was mainly in the elemental state. The activated carbons were prepared using steam activation method in a pilot scale set-up for the bio-char obtained from fast pyrolysis of whitewood. The elemental, porous structure, particle size, ash content, and thermogravimetric analyses were performed for the bio activated carbons. The activated carbons were impregnated using various precursors such as potassium and ammonium halides, with the halide loadings in the range of 0.1–

1.0 mol% of carbon content. It was observed that impregnation of the halide ions significantly improved the performance of the activated carbon (AC) for elemental mercury capture in nitrogen flow. For the same molar loading of halide ions, mercury removal efficiency increased in the following order: AC < Cl-impregnated AC < Br-impregnated AC < I-impregnated AC. Also, Hg removal efficiency of ammonium halide impregnated activated carbon was higher compared to potassium halide impregnated activated carbon, which is due to the better access of Hg to active sites in pores for ammonium halide impregnating agent. Changes in Hg removal efficiency with the process temperature showed that possibly the main mechanism for Hg capture by activated carbon changed from physisorption to chemisorption after impregnation. In the present study, the field test was performed for bio-based unimpregnated activated carbon and was observed to significantly reduce the carbon to mercury ratio for mercury removal from actual flue gas compared with that for the commercial activated carbon.

13/02065 Performance of double-layer biofilter packed with coal fly ash ceramic granules in treating highly polluted river water

Jing, Z. *et al. Bioresource Technology*, 2012, 120, 212–217.

To improve trickling filters' denitrification efficiency, a biofilter with a trickling upper layer and a submerged lower layer was developed and applied in treating highly polluted river water. It was packed with porous coal fly ash ceramic granules. Its start-up characteristics, influence of hydraulic loading rates (HLR), carbon/nitrogen (C/N) ratio and filter depth on pollutants removal were investigated. The results indicated this biofilter was started quickly in 16 days with river sediment as inoculum. Alternating nitrification and denitrification were achieved when water flowed downwards. COD and nitrogen were mainly removed in the upper layer and the lower layer, respectively. With HLR of 4.0–5.0 $m^3/(m^2 d)$, chemical oxygen demand (COD), ammonium (NH_4^+–N) and total nitrogen (TN) in the effluent were below 50, 5 and 15 mg/L, respectively. This biofilter removed more than 80% of COD, 85% of NH_4^+–N and 60% of TN with C/N ratios ranging from 6 to 10.

13/02066 The comparison of two activation techniques to prepare activated carbon from corn cob

Song, M. *et al. Biomass and Bioenergy*, 2013, 48, 250–256.

This study reports on the preparation of biomass-based activated carbons by the steam physical activation and KOH chemical activation methods. In addition, their adsorption performance was also investigated. By adjusting the reaction parameters, different carbon materials are prepared from corn residues and characterized using instrumental analyses such as scanning electron microscopy (SEM), X-ray diffraction (XRD), Fourier transform infrared (FTIR), and Brunauer–Emmett–Teller (BET). It is found that the synthesized activated carbons exhibit high surface area (1600 $m^2 g^{-1}$) and large pore volume (2.01 $cm^3 g^{-1}$). Furthermore, the high methylene blue and iodine adsorption value and a considerable CO_2 uptake (exceeding 1.5 $mmol\, g^{-1}$) are attained with the activated carbons, showing their potential usage for the CO_2 adsorbent.

13/02067 The sintering behavior of coal ash under pressurized conditions

Jing, N. *et al. Fuel*, 2013, 103, 87–93.

In order to obtain a detailed understanding of the effect of reaction atmospheres on the sintering temperature of coal ash under elevated pressure (0.7–1.0 MPa), a series of experiments have been conducted on the pressurized pressure-drop measuring device, together with analyses using X-ray diffractometer (XRD) analyser. The results show that the sintering temperatures decrease under the single gas and the atmospheres of mixed reaction gases with increasing in pressure (0.1–1.0 MPa). However, the extent of the decrease is not obvious in the pressure range from 0.7 to 1.0 MPa. The sintering temperatures of coal ash under the reducing reaction atmospheres (H_2, CO and gasification atmosphere) are lower than under oxidizing atmospheres (N_2, O_2, CO_2 and combustion atmosphere). In addition, the XRD patterns show that some minerals in coal ash, such as muscovite and anhydrite, are present as fluxing minerals that can reduce the sintering temperatures; while some feldspar minerals may react with other minerals to produce the low temperature eutectics with the rise in pressure, thus reducing the sintering temperatures.

13/02068 Unburned carbon from bagasse fly ash as a support for a VOC oxidation catalyst

Pande, G. *et al. Catalysis Today*, 2012, 190, (1), 47–53.

Unburned carbon in bagasse fly ash has been separated and activated under different conditions for use as a support for loading iron catalysts. These were tested for the total oxidation of n-butanol. The sequence of Fe loading affected the textural properties and the composition of the activated carbon. The sample loaded with Fe after activation had higher surface area and carbon content compared to sample activated after Fe loading. The sample with Fe loaded on separated carbon without activation had low surface area, low carbon content and poor activity in n-butanol oxidation. The Fe loaded activated carbon samples derived from bagasse fly ash had high surface area and their catalytic activities were comparable to that of commercial carbon. In comparison with the steam activated samples, the Fe loaded phosphoric acid activated carbon showed a higher thermal stability during the catalytic test due to the presence of C–O–P linkage.

05 NUCLEAR FUELS

Scientific, technical

13/02069 2-D numerical simulation of radionuclide transport in the lower Yangtze River

Zhang, W.-s. *et al. Journal of Hydrodynamics, Ser. B*, 2012, 24, (5), 702–710.

The assessment of the radiological impact of the liquid discharges from nuclear power plants is a major issue for the environmental protection. In this study, a numerical model for the radionuclide transport in the aquatic environment is built, based on the hydrodynamic equations, including the complete set of Saint-Venant equations, the sediment transport equations, with consideration of several different particle sizes and the deposition and erosion of the suspended sediments, and the radionuclide transport equations. The exchanges of radionuclides between water, suspended matter and bed sediments are described in terms of kinetic transfer coefficients. The model is used to simulate the transport of the radionuclides discharged from a planned nuclear power plant project to be sited along the lower Yangtze River. From the model results, one may see the detailed temporal-spatial evolution of the radionuclide contamination in the solution, in the suspended matter and in the bed sediments. The model can be used as a basic tool for studying the environmental impacts of the liquid discharges from nuclear facilities on a river system.

13/02070 A review of fission product sorption in carbon structures

Londono-Hurtado, A. *et al. Journal of Nuclear Materials*, 2012, 426, (1–3), 254–267.

This paper presents a review of results in the area of fission product sorption in carbon structures. Emphasis is placed on identifying those parameters of carbon-based materials that likely play a dominant role in fission product sorption and the extent to which these parameters have been studied. In particular, the authors discuss published studies of the effects of atomic structure, sp^2 to sp^3 bonding ratio, coke content, defect structures, irradiation level, and percentage of amorphous structures and porosity. Furthermore, the evolution of theories and models for carbon sorption are summarized. A review of the literature available to the authors reveals that the mechanics governing fission product sorptivity remain to be fully understood.

13/02071 Adapting plant measurement data to improve hardware fault detection performance in pressurised water reactors

Cilliers, A. C. and Mulder, E. J. *Annals of Nuclear Energy*, 2012, 49, 81–87.

With the fairly recent adoption of digital control and instrumentation systems in the nuclear industry a lot of research now focus on the development expert fault identification systems. The fault identification systems enable detecting early onset faults of fault causes which allows maintenance planning on the equipment showing signs of deterioration or failure. This includes valve and leaks and small cracks in steam generator tubes usually detected by means of ultrasonic inspection. Detecting faults early during transient operation in nuclear power plants is problematic due to the absence of a reliable reference to compare plant measurements with during transients. The distributed application of control systems operating independently to keep the plant operating within the safe operating boundaries complicates the problem since the control systems would not only operate to reduce the effect of transient disturbances but fault disturbances as well. This paper provides a method to adapt the plant measurements that isolates the control actions on the fault and re-introduces it into the measurement data, thereby improving plant diagnostic performance.

13/02072 An improved RELAP5/MOD3.3 reflood model considering the effect of spacer grids

Choi, T. S. *et al. Nuclear Engineering and Design*, 2012, 250, 613–625.
Various efforts have been made to improve the models and correlations of RELAP5/MOD3.3, which are activated only during the reflood phase of a large break loss-of-coolant-accident, the so-called 'reflood model'. The film boiling heat transfer regime was divided into three sub-regimes and appropriate wall-to-fluid heat transfer coefficient correlations were applied to each sub-regime. The models for estimating the size and the velocity of droplets were also modified. In addition, the authors introduced a special model to take into account the wall-to-fluid or interfacial heat transfer enhancement due to the spacer grids. The modified reflood model was assessed against eight FLECHT-SEASET tests and six RBHT tests having various initial and boundary conditions. The modified reflood model better predicted the PCTs and quench times of the eight FLECHT-SEASET tests: the RMS deviation of PCT predictions was reduced from 51.7 to 29.8 K and it was reduced from 81.9 to 33.5 s in the case of quench time predictions. As for the six RBHT tests, the quench times were predicted much better by the modified reflood model while not much improvement in the PCT predictions was obtained: the RMS deviation in quench time predictions was reduced from 322.5 to 132.1 s while the RMS deviation of PCT predictions were 62.5 and 53.1 K before and after the modifications, respectively. Additional calculations were conducted excluding the spacer grid heat transfer enhancement model to reveal that the model is essential to predict correctly the cladding temperature behaviours in the upper part of the core.

13/02073 Characterization of radioactive contaminants and water treatment trials for the Taiwan Research Reactor's spent fuel pool

Huang, C.-P. *et al. Journal of Hazardous Materials*, 2012, 233–234, 140–147.
There were approximately 926 m^3 of water contaminated by fission products and actinides in the Taiwan Research Reactor's spent fuel pool (TRR SFP). The solid and ionic contaminants were thoroughly characterized using radiochemical analyses, scanning electron microscopy equipped with an energy dispersive spectrometer (SEM-EDS), and inductively coupled plasma optical emission spectrometry (ICP-OES) in this study. The sludge was made up of agglomerates contaminated by spent fuel particles. Suspended solids from spent ion-exchange resins interfered with the clarity of the water. In addition, the ionic radionuclides such as ^{137}Cs, ^{90}Sr, U and α-emitters, present in the water were measured. Various filters and cation-exchange resins were employed for water treatment trials, and the results indicated that the solid and ionic contaminants could be effectively removed through the use of $<0.9\,\mu$m filters and cation exchange resins, respectively. Interestingly, the removal of U was obviously efficient by cation exchange resin, and the ceramic depth filter composed of diatomite exhibited the properties of both filtration and adsorption. It was found that the ceramic depth filter could adsorb β-emitters, α-emitters, and uranium ions. The diatomite-based ceramic depth filter was able to simultaneously eliminate particles and adsorb ionic radionuclides from water.

13/02074 Fusion energy conversion in magnetically confined plasma reactors

Dobran, F. *Progress in Nuclear Energy*, 2012, 60, 89–116.
One of the most pressing problems of this century is to solve the energy supply problem and in particular the development of fusion energy technology. Fusion powers the Sun and stars, but on Earth is difficult to achieve in a controlled manner. The International Thermonuclear Experimental Reactor (ITER) is the most technologically advanced machine where net energy from fusion is envisaged to be produced. But this will not be easy, since there are still open issues of plasma confinement, reactor materials, fuel supply, and heat removal. Efficient conversion of fusion energy into the thermal energy in a thermonuclear reactor is, therefore, of great technological relevance and in this paper the energy conversion in magnetically confined plasma reactors is addressed. The chamber wall surrounding the plasma is built from the plasma facing components and from the blanket and divertor modules where the fusion energy is converted into the thermal energy, tritium is produced, and the external components of the chamber are shielded from radiation. The useful materials for building the chamber wall components are low neutron activation steels, refractory metal alloys, and carbon fibre and silicon carbide reinforced composites. The suitable coolants of these components are high pressure helium gas and lithium-based liquid metals and molten salts, where the latter can also serve as tritium breeders. Some of these components will be tested in ITER and eventually may be employed for building demonstration fusion power plants envisaged to become operational during the second half of this century. High performance fusion energy conversion concepts being investigated include: Solid and liquid breeder blankets, separately cooled blankets and tritium breeders, high velocity helium jets for cooling plasma facing components, liquid metals flowing along the solid and through the porous metal walls facing the plasma, liquid metals and molten salts flowing through electrically insulated and non-insulated channels of blankets, and liquid metal heat pipes incorporated into the blankets and divertors for augmenting heat removal and achieving high thermal energy conversion efficiencies. The current fusion-to-thermal energy conversion technologies are, however, in an early stage of development and require reduced-activation, long life operation at high temperatures, resistance to plasma disruptions, and low fusion fuel retention materials, and innovative tritium breeding and heat removal concepts for building simple, reliable, safe, and efficient fusion energy technology.

13/02075 Helium turbomachinery operating experience from gas turbine power plants and test facilities

McDonald, C. F. *Applied Thermal Engineering*, 2012, 44, 108–142.
The closed-cycle gas turbine, pioneered and deployed in Europe, is not well known in the USA. Since nuclear power plant studies currently being conducted in several countries involve the coupling of a high temperature gas-cooled nuclear reactor with a helium closed-cycle gas turbine power conversion system, the experience gained from operated helium turbomachinery is the focus of this paper. A study done as early as 1945 foresaw the use of a helium closed-cycle gas turbine coupled with a high temperature gas-cooled nuclear reactor, and some two decades later this was investigated but not implemented because of lack of technology readiness. However, the first practical use of helium as a gas turbine working fluid was recognized for cryogenic processes, and the first two small fossil-fired helium gas turbines to operate were in the USA for air liquefaction and nitrogen production facilities. In the 1970s a larger helium gas turbine plant and helium test facilities were built and operated in Germany to establish technology bases for a projected future high efficiency large nuclear gas turbine power plant concept. This review paper covers the experience gained, and the lessons learned from the operation of helium gas turbine plants and related test facilities, and puts these into perspective since over three decades have passed since they were deployed. An understanding of the many unexpected events encountered, and how the problems, some of them serious, were resolved is important to avoid them being replicated in future helium turbomachines. The valuable lessons learned in the past, in many cases the hard way, particularly from the operation in Germany of the Oberhausen II 50 MWe helium gas turbine plant, and the technical know-how gained from the formidable HHV helium turbine test facility, are viewed as being germane in the context of current helium turbomachine design work being done for future high efficiency nuclear gas turbine plant concepts.

13/02076 Hydrogen deflagration simulations under typical containment conditions for nuclear safety

Yáñez, J. *et al. Nuclear Engineering and Design*, 2012, 250, 678–686.
This paper presents the modelling of low-concentration hydrogen deflagrations performed with the recently developed KYLCOM model specially created to perform calculations in large-scale domains. Three experiments carried out in THAI facility (performed in the frames of international OECD THAI experimental program) were selected to be analysed. The tests allow studying lean mixture hydrogen combustion at normal ambient, elevated temperature and superheated and saturated conditions. The experimental conditions considered together with the facility size and shape grant a high relevance degree to the typical nuclear power plant containment conditions. The results of the simulations were thoroughly compared with the experimental data, and the comparison was supplemented by the analysis of the combustion regimes taking place in the considered tests. Results of the analysis demonstrated that despite the comparatively small difference in mixture properties, three different combustion regimes can be definitely identified. The simulations of one of the cases required of the modelling of the acoustic–parametric instability which was carefully undertaken.

13/02077 Laser-induced photo transmutation of ^{126}Sn – a hazardous nuclear waste product-into short-lived nuclear medicine of ^{125}Sn

Irani, E. *et al. Energy Conversion and Management*, 2012, 64, 466–472.
Relativistic electrons, generated in the interaction of an ultra-intense laser pulse with plasma in front of a high-Z solid target, when passing near the nuclei of the solid target produce several MeV highly collimated Bremsstrahlung gamma beam, which can be used to induce photo-nuclear reactions. In this work the possibility of photo-induced transmutation (γn) of a nuclear waste of ^{126}Sn with a half-life of 100,000 years into ^{125}Sn with a half-life of 9.64 days was investigated for the first time. Calculations based on the available experimental data show that the Bremsstrahlung γ beam generated by irradiating a 2 mm thick tantalum target as a converter with 10^{20} W cm^{-2} μm^2 and 10 Hz table-top laser for an hour can produce 293 Bq activity in a 1 cm thick ^{126}Sn sample placed directly behind it. The remarkable feature of this work is to evaluate the optimal laser intensity to produce maximum

activity of 2257 Bq which is 1.18×10^{21} W cm^{-2} μm^2. The selective excitation of nuclear resonance states are discussed by studying the rate equations and calculating the Einstein coefficient. According to the calculations, relative decay rate of 0.0025, for two possible decay channels was achieved. The results show the most probable channel for this mechanism which has a good agreement with direct excitation process.

13/02078 Microbeam, timing and signal-resolved studies of nuclear materials with synchrotron X-ray sources

Ice, G. E. and Specht, E. D. *Journal of Nuclear Materials*, 2012, 425, (1–3), 233–237.

The development of ultra-brilliant synchrotron X-ray sources enables characterization methods that are particularly important for nuclear materials. This study discusses emerging synchrotron methods with unprecedented signal-to-noise, spatial and time resolution. Microprobe methods are discussed that extend virtually any X-ray characterization measurement to ultra-small sample volumes. This ability is critical to resolve heterogeneities in nuclear materials and for studies on volumes with vastly lower activity than are needed for traditional X-ray characterization. Specific methods discussed include microdiffraction for the characterization of local crystal structure and micro-spectroscopy techniques that allow for characterization of elemental distributions with sensitivity for daughter products, oxidation states and diffusion through buffer layers. Opportunities are also discussed that exploit the high brilliance and pulsed nature of synchrotron radiation to reduce backgrounds from sample radiation and to study materials dynamics.

13/02079 Modelling of fission gas release from irradiated UO_2 fuel under high-temperature annealing conditions

Veshchunov, M. S. and Shestak, V. E. *Journal of Nuclear Materials*, 2012, 430, (1–3), 82–89.

The new model for the vacancy field evolution in grains during annealing of irradiated fuel was developed and implemented in the MFPR code. The model simulates time and spatial variation of the vacancy concentration in the presence of extended vacancy sources (grain boundaries and dislocations) and sinks (growing intragranular bubbles). Being combined with the models for dislocation creep and for bubbles biased migration in the vacancy gradient, the new model self-consistently describes the processes of gas release and microstructure evolution observed in the annealing tests.

13/02080 Neutronic characteristics of linear-assembly breed-and-burn reactors

Petroski, R. *et al. Nuclear Engineering and Design*, 2012, 250, 364–384.

Linear-assembly breed-and-burn (B&B) reactors are B&B reactors that use axially connected assemblies similar to conventional LWR or fast reactor fuel assemblies. Methods for analysing linear-assembly B&B reactors and their fuel cycles are developed and applied. General neutronic characteristics of linear-assembly B&B reactors are analysed, including the effects that burnup, shuffling sequence, and radial and axial size have on equilibrium-cycle k-effective. The mechanisms that give rise to a highly peaked axial burnup distribution are explained, and a method for predicting peak burnup vs k-effective based on infinite-medium depletion calculations is developed. Next, the neutron excess concept from previous studies of B&B reactors is extended to apply to linear-assembly B&B reactors, which allows the amount of starter fuel needed to establish a given equilibrium cycle to be calculated. Several example applications of the neutron excess formulation are given. First, an example model of a linear-assembly B&B reactor is analysed to find the neutron excess cost of an equilibrium cycle. Second, simple one-dimensional models are used to predict the neutron excess value obtainable from different starter fuel configurations. Finally, these ideas are applied to design a fuel cycle consisting of linear-assembly B&B reactors and fuel recycling via a melt refining process. The neutron excess concept is used to design an appropriate starter fuel configuration made from melt refined fuel, which is then used in a transition model that shows how the desired equilibrium cycle can be established. The doubling time of this fuel cycle is calculated as an example of what is achievable using B&B reactors.

13/02081 Numerical simulation of stochastic point kinetic equation in the dynamical system of nuclear reactor

Ray, S. S. *Annals of Nuclear Energy*, 2012, 49, 154–159.

This paper investigates the numerical approximation methods, applied to calculate efficiently the solution for stochastic point kinetic equations in nuclear reactor dynamics. A system of Itô stochastic differential equations was analysed to model the neutron density and the delayed neutron precursors in a point nuclear reactor. The resulting system of Itô stochastic differential equations were solved over each time-step size. The methods were verified by considering different initial conditions, experimental data and over constant reactivities. The computational results indicate that the methods are simple and suitable for solving stochastic point kinetic equations. In this paper, a numerical investigation was performed in order to observe the random fluctuations in neutron and precursor population dynamics in subcritical and critical reactors.

13/02082 Plant dynamics studies towards design of plant protection system for PFBR

Natesan, K. *et al. Nuclear Engineering and Design*, 2012, 250, 339–350.

Prototype fast breeder reactor (PFBR) is a 500 MWe (1250 MWt) liquid sodium-cooled pool-type reactor currently under construction in India. For a safe and efficient operation of the plant, it is necessary that the reactor is protected from all the transients that may occur in the plant. In order to accomplish this, adequate number of SCRAM parameters is required in the plant protection system with reliable instrumentation. For identifying the SCRAM parameters, the neutronic and thermal hydraulic responses of the plant for various possible events need to be established. Towards this, a one-dimensional plant dynamics code DYANA-P has been developed with thermal hydraulic models for reactor core, hot and cold pools, intermediate heat exchangers, pipelines, steam generator, primary sodium circuits and secondary sodium circuits. The code also incorporates neutron kinetics and reactivity feedback models. By a comprehensive plant dynamics study an optimum list of SCRAM parameters and the maximum permissible response time for various instruments used for deriving them have been arrived at.

13/02083 Single-pass flow-through test elucidation of weathering behavior and evaluation of contaminant release models for Hanford tank residual radioactive waste

Cantrell, K. J. *et al. Applied Geochemistry*, 2013, 28, 119–127.

Contaminant release models are required to evaluate and predict long-term environmental impacts of residual amounts of high-level radioactive waste after clean-up and closure of radioactively contaminated sites such as the DOE's Hanford Site. More realistic and representative models have been developed for release of U, Tc and Cr from Hanford Site tanks C-202, C-203, and C-103 residual wastes using data collected with a single-pass flow-through test (SPFT) method. These revised models indicate that contaminant release concentrations from these residual wastes will be considerably lower than previous estimates based on batch experiments. For U, a thermodynamic solubility model provides an effective description of U release, which can account for differences in pore fluid chemistry contacting the waste that could occur through time and as a result of different closure scenarios. Under certain circumstances in the SPFT experiments various Ca-rich precipitates (Ca phosphates and calcite) form on the surfaces of the waste particles, inhibiting dissolution of the underlying U phases in the waste. This behaviour was not observed in previous batch experiments. For both Tc and Cr, empirical release models were developed. In the case of Tc, release from all three wastes was modelled using an equilibrium K_d model. For Cr release, a constant concentration model was applied for all three wastes.

13/02084 Thermal evaluation of uranium silicide miniplates irradiated at high heat flux

Guillen, D. P. *Nuclear Engineering and Design*, 2012, 250, 237–246.

The gas test loop (GTL)-1 irradiation experiment was conducted in the Advanced Test Reactor (ATR) to assess corrosion performance of proposed booster fuel at heat flux levels ~30% above the design operating condition. Sixteen miniplates fabricated from 25% enriched, high-density (4.8 g U/cm^3) U_3Si_2/Al dispersion fuel with 6061 aluminum cladding were subjected to peak beginning of cycle (BOC) heat fluxes ranging from 411 to 593 W/cm^2. No adverse impacts to the miniplates were observed at these high heat flux levels. A detailed finite element model was constructed to calculate temperatures and heat flux for an as-run cycle average effective ATR south lobe power of 25.4 MW(t). Miniplate heat flux levels and fuel, cladding, hydroxide, and coolant–hydroxide interface temperatures were calculated using the average hydroxide thickness on each miniplate measured during post-irradiation examination. The miniplates displayed the ability to withstand peak conditions exceeding the expected design conditions for the BFFL booster fuel, thus establishing this fuel type as a suitable candidate for fuel qualification experiments. A more in-depth understanding of the hydroxide formation processes at high heat flux is necessary. Processes or conditions that contribute to keeping the hydroxide film thin, thus improving fuel performance, are of interest.

13/02085 Transient analysis of break below the grid in Tehran research reactor using the newly enhanced COBRA-EN code

Aghaie, M. *et al. Annals of Nuclear Energy*, 2012, 49, 1–11.

Recent availability of high performance computers and computational methods along with continuing increase in operational experience necessitate revising some operational constrains and conservative safety margins. Implementation of advanced methods constitute a real necessity in the safety and design analysis and allow obtaining more realistic simulation of the processes taking place during the normal operations and transients. In this paper, COBRA-EN thermal–hydraulic code is extended and upgraded to include analysis of plate type fuels in research reactors. Furthermore, the convection heat transfer coefficient in the code is modified and a simple model of natural convection is added and a procedure to take hot channel data or other required information in each time step is included for post-processing of the results. To evaluate the capability of the upgraded code three cases of break below the grid accident in Tehran research reactor (TRR) core which contains plate type fuels are simulated. The safety analysis report of TRR confirms the results, convergence rate and reliability of developed code.

Economics, policy, supplies, forecasts

13/02086 Analysis of the qualified life extension of nuclear safety systems through modulated Poisson point processes

Saldanha, P. L. C. and Frutuoso e Melo, P. F. *Progress in Nuclear Energy*, 2012, 60, 117–128.

The modulated power law process (MPLP) is a three-parameter stochastic point process that can be used to describe the failure times of repairable systems. While the non-homogeneous Poisson process (NHPP) or the renewal process (RP) implies that a system is exactly on the same condition just after a repair as just before a failure, the MPLP allows for the system to be affected both by failure and repair. For this reason this model is adequate for evaluating the recurrent events that incorporate both time trends and effects of past events such as the renewal type behaviour. The purpose of this paper is to evaluate the MPLP as a model for the rate of occurrence of failures (ROCOF) of repairable systems to decide for an extension of qualified life in the context of a license renewal of a nuclear power plant. The analysis was carried out considering some field data spanning a 2300 calendar day period, which is approximately equivalent to four burn-up cycles and refuelling periods. The reliability is estimated, and maintenance strategies are discussed, concerning the results of the case study presented. As a conclusion, the MPLP is adequate for modelling the rate of occurrence of failures that are time dependent, and can be used where aging mechanisms are present in the operation of repairable systems. This means that equipment characteristics that are important may be inserted into the model and the results can help make decisions in the context of maintenance programs, as is the case with the maintenance rule concept that has been proposed by the US Nuclear Regulatory Commission and has just been implemented in nuclear power plants in Brazil, for instance. The difficulty with data acquisition for applying point processes is discussed throughout.

13/02087 Application of risk-based approach to post-closure safety assessment in radioactive waste disposal: an integration of complex radiation exposure situations

Seo, E. J. *et al. Annals of Nuclear Energy*, 2012, 49, 96–101.

Based on the concept of risk, the post-closure safety criteria for high-level radioactive waste (HLW) disposal are under development in Korea. For compliance with the safety criteria of disposal, the risk-based safety assessment methodology should be implemented. In this paper, the authors suggest a risk-based approach to safety assessment for Korea radioactive waste disposal to evaluate an aggregative radiological risk for scenarios of complex radiation exposure situations; accordingly, the most plausible three cases are carefully selected. This risk-based approach deals with the scenarios from the viewpoint of the receptor to estimate the total risk. For respective exposure situations, it considers the occurrence probabilities of the relevant exposure scenarios as the probability of giving rise to doses to estimate the total risk to a representative person by aggregating the respective risks. In addition, the probability of an exposure scenario is estimated on the assumption that the initiating events influence release mechanisms and transport pathways. This integrated approach enables a systematic risk assessment and is informative when judging the probable overall risk for complex exposure situations of radioactive waste disposal. In this paper, the risk-based approach is applied for the case of the low and intermediate level radioactive waste disposal, and also the results should be applicable to the HLW disposal facilities.

13/02088 Measuring variability of procedure progression in proceduralized scenarios

Kim, Y. *et al. Annals of Nuclear Energy*, 2012, 49, 41–47.

Various performance shaping factors (PSFs) have been presented to explain the contributors to unsafe acts in a human failure event or predict a human error probability of new human performance. However, because most of these parameters of a human reliability analysis (HRA) depend on the subjective knowledge and experience of HRA analysers, the results of an HRA insufficiently provide unbiased standards to explain human performance variations or compare collected data with other data from different analysers. To secure the validity of the HRA results, a quantitative measure is proposed which represents the variability of procedure progression (VPP) in proceduralized scenarios. A VPP measure shows how differently the operators follow the steps of the procedures. This paper introduces the sources of the VPP measure and relevance to PSFs. The assessment method of the VPP measure is also proposed, and the application examples are shown with a comparison of the performance time. Although more empirical studies should be conducted to reveal the relationship between the VPP measure and other PSFs, it is believed that the VPP measure provides evidence to quantitatively evaluate human performance variations and to cross-culturally compare the collected data.

13/02089 Nuclear energy – any solution for sustainability and climate protection?

Mez, L. *Energy Policy*, 2012, 48, 56–63.

For the future of nuclear power it will be decisive whether or not nuclear fission technologies offer a sustainable solution to global energy problems. The history of nuclear energy has shown that reconsideration has usually taken place following major nuclear accidents. The 25th anniversary of the meltdown in Chernobyl was in 2011. This disaster, which took place in the Ukraine on 26 April 1986, accelerated the phase-out of nuclear energy in a host of Western industrialized countries, which had already started in the USA in the 1970s. Following the meltdown in the Three Mile Island 2 reactor in Harrisburg, Pennsylvania in 1979, almost two-thirds of US nuclear power plant projects were cancelled. Nuclear programmes in Austria and Denmark were postponed in Europe even before the disaster in Chernobyl. After 1986, Italy, the Netherlands, Belgium, Sweden and Germany resolved to phase-out nuclear energy and have in part already done so. Spain has a complete nuclear moratorium. This contrasts with developments in Eastern Europe. In the wake of Chernobyl the anti-nuclear power movement in the Soviet Union attained a freeze on nuclear projects and a nuclear moratorium during *glasnost* and *perestroika*, but following the end of the Cold War technocrats in the energy sector were able to resume old programmes and projects. Central and Eastern European states assiduously continued along the path of developing nuclear technology following national independence and the disintegration of the Soviet Union. Only in Poland was the construction of a nuclear power plant in Zarnowiec, west of Gdansk, stopped by a local referendum. In the wake of the Fukushima nuclear accident, Switzerland was the first European country to announce plans to phase out nuclear power. The Swiss government decided on 26 May 2011 that the country's five nuclear power stations would close gradually over the next 20 years. And Germany decided in June 2011 to gradually phase out all remaining 17 nuclear power plants by 2022, starting with eight reactors in 2011. The German Atomic Energy Act Amendment is in force since 6 August 2011. Finally, the new Belgian government aims to shut down three of seven nuclear reactors by 2015 with remaining nuclear power to be taken off the grid by 2025.

13/02090 Nuclear energy consumption, oil consumption and economic growth in G-6 countries: bootstrap panel causality test

Chu, H.-P. and Chang, T. *Energy Policy*, 2012, 48, 762–769.

This study applies bootstrap panel Granger causality to test whether energy consumption promotes economic growth using data from the Group of Six (G-6) countries over the period of 1971–2010. Both nuclear and oil consumption data are used in this study. Regarding the nuclear consumption-economic growth nexus, nuclear consumption causes economic growth in Japan, the UK, and the USA; economic growth causes nuclear consumption in the USA; nuclear consumption and economic growth show no causal relation in Canada, France and Germany. Regarding oil consumption-economic growth nexus, it was found that there is one-way causality from economic growth to oil consumption only in the USA, and that oil consumption does not Granger cause economic growth in G-6 countries except Germany and Japan. The results have important policy implications for the G-6 countries within the context of economic development.

13/02091 On the corrosion behavior of zircaloy-4 in spent fuel pools under accidental conditions

Lavigne, O. *et al. Journal of Nuclear Materials*, 2012, 426, (1–3), 120–125.

After zircaloy cladding tubes have been subjected to irradiation in the reactor core, they are stored temporarily in spent fuel pools. In case of an accident, the integrity of the pool may be affected and the composition of the coolant may change drastically. This was the case in Fukushima Daiichi in March 2011. Successive incidents have led to an increase in the pH of the coolant and to chloride contamination. Moreover, water radiolysis may occur owing to the remnant radioactivity of the spent fuel. This study evaluates the corrosion behaviour of oxidized Zr-4 (in autoclave at 288 °C for 32 days) in function of the pH and the presence of chloride and radical forms. The generation of radicals is achieved by the sonolysis of the solution. It appears that the increase in pH and the presence of radicals lead to an increase in current densities. However, the current densities remain quite low (depending on the conditions, between 1 and $10\,\mu\mathrm{A\,cm}^{-2}$). The critical parameter is the presence of chloride ions. The chloride ions widely decrease the passive range of the oxidized samples [the pitting potential is measured around +0.6 V (vs SCE)]. Moreover, if the oxide layer is scratched or damaged (which is likely under accidental conditions), the pitting potential of the oxidized sample reaches the pitting potential of the non-oxidized sample [around +0.16 V (vs SCE)], leaving a shorter stable passive range for the Zr-4 cladding tubes.

13/02092 The future of the nuclear industry reconsidered: risks, uncertainties, and continued promise

Kessides, I. N. *Energy Policy*, 2012, 48, 185–208.

Sceptics point out, with some justification, that the nuclear industry's prospects were dimmed by escalating costs long before Fukushima. If history is any guide, one direct consequence of the calamity in Japan will be more stringent safety requirements and regulatory delays that will inevitably increase the costs of nuclear power and further undermine its economic viability. For nuclear power to play a major role in meeting the future global energy needs and mitigating the threat of climate change, the hazards of another Fukushima and the construction delays and costs escalation that have plagued the industry will have to be substantially reduced. One promising direction for nuclear development might be to downsize reactors from the gigawatt scale to less-complex smaller units that are more affordable. Small modular reactors (SMRs) are scalable nuclear power plant designs that promise to reduce investment risks through incremental capacity expansion; become more standardized and reduce costs through accelerated learning effects; and address concerns about catastrophic events, since they contain substantially smaller radioactive inventory. Given their lower capital requirements and small size, which makes them suitable for small electric grids, SMRs can more effectively address the energy needs of small developing countries.

13/02093 The simulation of I&C in accident analyses of nuclear power plants

D'Auria, F. *et al. Nuclear Engineering and Design*, 2012, 250, 656–663.

The best estimate plus uncertainty (BEPU) approach constitutes a valuable and, under some circumstances, an unavoidable tool to demonstrate the safety of nuclear power plants (NPP). Within the licensing process of the Atucha II pressurized heavy water reactor (PHWR) the BEPU approach has been followed for issuing the Chapter 15 of the Final Safety Analysis Report (FSAR). Namely, the BEPU approach replaced the classical conservative approach for issuing the Atucha II PHWR FSAR Chapter 15. The key steps of the entire process are basically two: (a) the selection of postulated initiating events (PIE) and, (b) the analysis of each PIE by best estimate models supported by uncertainty evaluation. Otherwise, key elements of the approach are: (1) availability of qualified computational tools including suitable uncertainty method; (2) demonstration of quality of any calculation result; (3) achieving the acceptability and endorsement by the licensing authority. The key features of the BEPU approach are discussed in a companion paper. The present paper is concerned with the planning of the analyses at the item (b). The need to simulate the performance of the instrumentation and control system is demonstrated.

13/02094 The sources of divergent practices in China's nuclear power sector

Chi, C. S. F. and Chen, L. *Energy Policy*, 2012, 48, 348–357.

Unlike markets that were early developers of reactors, which are dominated by single technologies, China's nuclear power sector adopts and imports multiple technologies. Even after the Chinese government introduced a policy to develop a standardized, unified, and technologically advanced nuclear power sector in the early 2000s, different technologies continue to be imported. This study uses an institutional lens to explore the decoupling of policy intentions and implementation. The three phases of nuclear technology imports that occurred between the 1980s and 2010 are examined and compared. Data are collected from multiple sources, including the diary of a major decision-maker, news articles, project websites, a regulation database, domestic journal articles, and interviews with industry experts. Using interactive content analysis, this study identifies the multiple policy principles and goals of different domains that led to different import arrangements and interpretations of the available foreign technology. New arrangements do not replace but overlap the existing ones that are perpetuated by the actors who benefit from them. The results show that the multiplicity of China's nuclear power sector, coupled with the government's late attempts at standardization, contributes to diversified policy implementation. They provide important policy implications for the sustainable development of the sector.

13/02095 Thermal hydraulic and safety analysis for core conversion (HEU–LEU) of Syrian miniature neutron source reactor

Omar, H. *et al. Progress in Nuclear Energy*, 2012, 60, 140–145.

The paper presents the behaviour and properties analysis of the low-enriched uranium fuel compared with the original high-enriched uranium fuel. The miniature neutron source reactor (MNSR) reactor core was modelled with both fuel materials and the reactor behaviour was studied during the steady-state and abnormal conditions. The MERSAT code was used in the analysis. The steady-state thermal hydraulic analysis results were compared with that obtained from the experimental results hold during commissioning the Syrian MNSR. Comparison with experimental data shows that the steady-state behaviour of the HEU core was accurately predicted by the MERSAT code calculations. The validated model was then used to analyse LEU cores with two proposed UO_2 fuel-pin designs. With each LEU core, the steady-state and 3.77 mk rod withdrawal transient were run and the results were compared with the available published data in the literatures for the low enriched uranium fuel core. The results reveal that the low enriched uranium fuel showed a good behaviour and the peak clad temperatures remain well below the clad melting temperature during reactivity insertion accident.

13/02096 Using risk tolerance criteria to determine safety integrity levels for safety instrumented functions

Baybutt, P. *Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 1000–1009.

Standards and industry guidelines for safety instrumented systems (SISs) describe the use of hazard and risk analysis to determine the risk reduction required, or safety integrity levels (SILs), of safety instrumented functions (SIFs) with reference to hazardous events and risk tolerance criteria for them. However, significant problems are encountered when putting this approach into practice. There is ambiguity in the meaning of the term 'hazardous event'. Notably, even though it is a key concept in the process-sector-specific SIS standard, IEC 61511/ISA 84, it is not defined in the standard. Consequently, risk tolerance criteria for hazardous events are ill-defined and, therefore, they are not the most appropriate criteria to use. Most current approaches to SIL determination use them and therefore they are flawed fundamentally. An informed decision on the tolerability of risk for a facility cannot be made by determining only the tolerability of risk for individual hazardous events. Rather, the tolerability of the cumulative risk from all hazard scenarios and their hazardous events for a facility must be determined. Such facility risk tolerance criteria are the type used by regulators. This issue applies to all per event risk tolerance criteria. Furthermore, determining the tolerability of risk for a facility based only on the risks of single events, be they hazard scenarios or hazardous events, and comparing them to risk tolerance criteria for the events is not meaningful because there is no consideration of how many such events can actually occur and, therefore, no measure of the total risk. The risks from events should be summed for a facility and compared with overall facility risk tolerance criteria. This paper describes and illustrates SIL determination using a risk model implemented within the framework of layers of protection analysis that overcomes these problems. The approach allows the allocation of risk across companies, facilities, processes, process units, process modes, etc., to be managed easily.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

13/02097 A domestic CHP system with hybrid electrical energy storage

Chen, X. P. *et al. Energy and Buildings*, 2012, 55, 361–368.

Combined heat and power (CHP) is widely regarded as one of the most promising technologies to resolve energy-related problems, such as primary energy saving, emission reducing etc. Domestic CHP is the energy system applied to the household sector to supply both electric and heat energy to users. Due to the dissimilar characteristics between household electricity and heat demands, conventional off-grid CHP systems may not satisfy both of the demands simultaneously. This study developed a domestic CHP system in which an engine-based CHP fuelled by biofuels was integrated with a hybrid electric energy storage system and operated under following electric load energy management strategy. Experimental tests validate the feasibility of this application and the results show that the system can satisfy the fluctuant energy demands in a domestic dwelling. The overall energy efficiency has been improved by 47.86% compared to conventional CHP.

13/02098 A semi-automatic approach for thermographic inspection of electrical installations within buildings

Nazmul Huda, A. S. *et al. Energy and Buildings*, 2012, 55, 585–591.
Maintaining the reliability of electrical installation has become part of the energy efficiency practices in building. The degradation of electrical installations can cause overheating, which can lead to subsequent failure of the equipment that can potentially result in unplanned power outages, possible injury and fire hazard. In addition, the efficiency of an electrical system becomes low prior to failure, thus energy is spent generating heat and causing unnecessary energy loses. Therefore, early prevention is required to avoid this situation by monitoring the reliability of the electrical installations through energy audit practices. This article proposes a semi-automatic approach for evaluating the thermal condition of electrical installations within the building in Malaysia by analysing its infrared image. Initially the interest regions of the images are manually segmented. Then the statistical features of first order histogram and grey level co-occurrence matrix features as well as the differences of feature parameters between hot and reference regions are extracted from segmented regions. Principle component analysis is applied for the best features selection and at the final stage, the condition of electrical equipment will be classified using multi-layered perceptron neural network. The performances of multi-layered perceptron networks have been compared and tested with various training algorithms. The classification accuracy of multi-layered perceptron networks are also compared with discriminant analysis classifier and it is found that the multi-layered perceptron network using Levenberg–Marquardt algorithm gives the best testing performance. The result shows that the maximum testing accuracy 78.5% was obtained.

13/02099 A trigeneration system based on compressed air and thermal energy storage

Li, Y. *et al. Applied Energy*, 2012, 99, 316–323.
This paper presents a novel energy storage system which stores excessive energy in the form of compressed air and thermal heat. It is different from the conventional compressed air energy storage technology in that the new system allows trigeneration of electrical, heating and cooling power in energy releasing process. Uniquely, the cooling power from this system is generated by direct expansion of compressed air instead of the use of absorption chilling technology. In addition, the system can meet the end users' demands for electricity, and heating and cooling powers through controlling the inlet pressure and temperature of an air based expander. A new parameter, the comprehensive efficiency, is proposed to evaluate the performance of the trigeneration system. Energy requirements of a small office building located in Chicago is used for the evaluation. The results show that the comprehensive efficiency of the system is very high ($\sim$50%) in winter months when no cooling is needed. In summer months, due to the high power consumption in air compression process and inefficient expansion of the compressed air (for cooling power production) the comprehensive efficiency decreases to about 30%. However such a value is still higher than the conventional trigeneration system based on absorption chilling technology. The system is therefore very promising for practical applications particularly for the use of renewable energy due to good flexibility and simple configuration.

13/02100 Assessment of load-following capability of VHTR cogeneration systems

Sato, H. *et al. Annals of Nuclear Energy*, 2012, 49, 33–40.
A newly-proposed control system design for the GTHTR300C, a nuclear power and heat cogeneration system employing a very high temperature reactor (VHTR), offering load-following capability is presented. The system is designed to follow significant seasonal variations of electric load demand. It combines several fundamental control methods including inventory control used to adjust primary coolant pressure, flow bypass control used to regulate the coolant flow rate and turbine inlet temperature, and additional flow control to vary the IHX heat rate. The goal of the control system design is such that the wide range of load-following capability can be performed at constant reactor power and thermal efficiency, which maximizes plant economics, while minimizing transient thermal stresses in the reactor equipment. The control simulation of a representative load-following operation is carried out using a system analysis code and discussed in the paper. The results of the simulation show that the design goal can be effectively met by monitoring and controlling constant a few selected operating parameters of reactor and gas turbine including reactor outlet temperature, turbine inlet temperature and speed. The original control system design shows that load-following operation at constant reactor power and thermal efficiency by a VHTR power and heat cogeneration system is feasible.

13/02101 Battery storage system for residential electricity peak demand shaving

Leadbetter, J. and Swan, L. *Energy and Buildings*, 2012, 55, 685–692.
This article presents the modelling, simulation, and sizing results of battery energy storage systems for residential electricity peak shaving. Realistic 5 min time-step electricity profiles were input to an energy storage model with the objective of reducing the peak electricity demand seen by the electricity grid. The model simulates and provides performance results of a range of battery and inverter sizes specific to a variety of residential houses. The results suggest typical system sizes range from 5 kWh/2.6 kW for low electricity intensity homes to 22 kWh/5.2 kW for electricity intense homes with electric space heating. Based on the resulting storage system cycling profile and data provided by other researchers, the battery life is estimated to be in the range of 10–20 years for this application.

13/02102 Cogeneration targeting for site utility systems

Ghannadzadeh, A. *et al. Applied Thermal Engineering*, 2012, 43, 60–66.
Estimation of cogeneration potential prior to the design of the total site utility system is vital to set targets on site fuel demand and steam flowrate as well as heat and power production. This paper presents in detail the iterative bottom-to-top model (IBTM) as a new shaftwork targeting model which facilitates the targeting stage. The IBTM calculates the temperature of steam mains, steam flowrate and shaft power generated by the steam turbines in expansion zones of the site utility grand composite curve from bottom to top using a simple steam turbine expansion model with a constant isentropic efficiency. Unlike the existing models, IBTM provides the degree of superheat at process steam generators and steam boiler house. Through a case study of a refinery plant, the applicability of the IBTM in total site analysis is presented. It has been shown that the features of IBTM make it preferable for its implementation in flexible targeting tools to set realistic targets on the site fuel demand and the cogeneration at the early stages of design.

13/02103 Development of new materials for alkaline electrolysers and investigation of the potential electrolysis impact on the electrical grid

Cruden, A. *et al. Renewable Energy*, 2013, 49, 53–57.
This paper discusses development of new materials for alkaline electrolysers and assesses the impact of large penetrations of electrolysis plants on the electrical grid. New electrolyser electrodes were produced by a synthesis method of nickel electroplated with carbon catalyst consisting of molybdenum-resorcinol-formaldehyde (Mo RF), and carbon aerogel of surface area $>700\,\mathrm{m^2/g}$ and pore size of 4 nm, followed by an impregnation of molybdenum as a catalyst before deposition on nickel thus creating Ni–Mo RF electrodes. Another electrode made from vulcan–carbon–platinum powder was used to produce Ni–C–Pt electrodes. The different electrodes were compared by analysis of kinetic reaction measurements using polarization techniques and electrochemical impedance methods. An experiment was carried out to measure the AC and DC harmonics and the efficiency of the electrical parts of an operational $1\,\mathrm{N\,m^3/hr}$ electrolyser. In addition, the power system impact analysis of two Alkaline Electrolysis plants connected to the IEEE30 standard power system model was studied in MATLAB environment.

13/02104 Distribution grid reconfiguration reduces power losses and helps integrate renewables

Lueken, C. *et al. Energy Policy*, 2012, 48, 260–273.
A reconfigurable network can change its topology by opening and closing switches on power lines. This study uses real wind, solar, load, and cost data and a model of a reconfigurable distribution grid to show that reconfiguration allows a grid operator to reduce operational losses as well as to accept more intermittent renewable generation than a static configuration can. Net present value analysis of automated switch technology shows that the return on investment is negative for this test network when considering only loss reduction, but that the investment is attractive under certain conditions when reconfiguration is used to minimize curtailment.

13/02105 Electric power generation by a submersible microbial fuel cell equipped with a membrane electrode assembly

Min, B. *et al. Bioresource Technology*, 2012, 118, 412–417.
Membrane electrode assemblies (MEAs) were incorporated into the cathode chamber of a submersible microbial fuel cell (SMFC). A close contact of the electrodes could produce high power output from SMFC in which anode and cathode electrodes were connected in parallel. In polarization test, the maximum power density was $631\,\mathrm{mW/m^2}$ at current density of $1772\,\mathrm{mA/m^2}$ at $82\,\Omega$. With $180\text{-}\Omega$ external resistance,

one set of the electrodes on the same side could generate more power density of $832 \pm 4\,\mathrm{mW/m^2}$ with current generation of $1923 \pm 4\,\mathrm{mA/m^2}$. The anode, inclusive a biofilm behaved ohmic, whereas a Tafel type behaviour was observed for the oxygen reduction. The various impedance contributions from electrodes, electrolyte and membrane were analysed and identified by electrochemical impedance spectroscopy. Air flow rate to the cathode chamber affected microbial voltage generation, and higher power generation was obtained at relatively low air flow less than 2 mL/min.

13/02106 Electricity production by biomass steam gasification using a high efficiency technology and low environmental impact

Molino, A. *et al. Fuel*, 2013, 103, 179–192.

The integration of biomass gasification and fuel cell represents in theory an energy effective solution for decentralized CHP production. The main goal of the paper is the integration of a biomass steam gasification plant with a molten carbonate fuel cell with the advantage of a power production plant with a low CO_2 emission compared with the traditional power generator fuelled by fossil. The integration of a steam gasification pilot plant coupling with a molten carbonate fuel cell has, in principle, many advantages, not only, of course, compared to conventional power generation systems, but also compared to other technologies for energy conversion of biomass. Distributed generation with small plants with high efficiency is particularly suitable in the case of biomass, because it reduces the problems associated with their procurement and promote its sustainable use. The proposed integrated system results in significant environmental benefits compared to traditional power generation, derived from both the type of fuel used, and the characteristics of the conversion device.

13/02107 Energy and exergy efficiency of a building internal combustion engine trigeneration system under two different operational strategies

Espirito Santo, D. B. *Energy and Buildings*, 2012, 53, 28–38.

Trigeneration systems can be a good choice for distributed power production in buildings with coincident energy demands. Demand in a building can vary with the hour of day, activity, occupancy and climate, and can fluctuate widely. Trigeneration systems will achieve a high energy utilization factor (EUF) at hours when the degree of coincidence is high, but a lower EUF when coincidence is low. In order to improve performance, energy of the prime mover should be compared with site energy demands. Simulation can contribute to improving design of cogeneration systems. This paper presents a computational hourly profile simulation methodology that combines into a single algorithm curve fittings from the literature and manufacturer data, mathematical representations of physical phenomena, and thermodynamic properties. This simulation methodology was used to predict the performance of a given cogeneration concept under two different operational strategies. Performance evaluation was based on EUF, exergy efficiency and primary energy savings (PES) analysis. Results obtained in the case study revealed an EUF between 65% and 81%, and an exergy efficiency between 35% and 38.4%. The PES analysis showed that the proposed cogeneration system can compete with high-efficiency thermal plants.

13/02108 Examination of major factors affecting voltage variation on distribution feeders

Chen, T.-H. *et al. Energy and Buildings*, 2012, 55, 494–499.

The purpose of this paper is to investigate various voltage-affecting factors for a feasibility study of system voltage control of a distribution network. The existing voltage control techniques of a distribution feeder can be classified in two groups: system planning techniques and equipment control techniques. The system planning techniques consist of (1) the system short-circuit capacity, (2) the rated capacity of the substation transformer, (3) the percentage impedance of the substation transformer, (4) the size of the primary feeder conductor, (5) the length of the primary feeder, (6) the loads on primary feeder, (7) the distribution of discrete feeder loads, (8) the power factors of feeder loads, (9) the total loads of other feeders supplied by the same substation transformer, (10) the imbalance of feeder loads and (11) the voltage level of the primary feeder. The system planning techniques are only employed in system design and planning stages. Although the system planning techniques are not suitable for regulating the real-time feeder voltage, the effect of system planning techniques is overall. The application of equipment control techniques is a good way to maintain the node voltages along a distribution feeder within a permissible range. The equipment control techniques can be applied to regulate the node voltages along a feeder in real-time system operation because of high state controllability. Usually, the equipment control techniques applied to the voltage quality of distribution feeders consist of under load tap changer (ULTC) transformer, dynamic voltage restorer (DVR), automatic voltage regulator (AVR), static var compensator (SVC), shunt capacitor (SC) and so on. The control equipment for network voltage can be classified in two groups: voltage control equipment and current control equipment. ULTC transformer and AVR that are used to regulate the voltages of primary distribution feeders belong to the first group, the voltage control equipment. DVR, SVC and SC that are applied to regulate the currents in feeder segments belong to the second group, the current control equipment. The voltage control equipment can be adopted to regulate the node voltages of the feeders in the concerned region and the influenced area may cover an entire or a local area of a feeder. For example, if the tap position of a ULTC transformer is changed, its effect on the node voltages are from the busbar on the secondary side of the substation transformer to the end of a feeder. DVR and AVR do affect the voltages at the downstream systems of device-connection points. And, SVC and SC do affect the voltages in the vicinity of device-connection points. To maintain operation security and the voltage quality of a power system, the system planning techniques and the equipment control techniques are both required. The results of this paper are of value in understanding the effects of major factors affecting the voltage variation of primary distribution feeders.

13/02109 Experimental analysis of peak power output of a thermoelectric liquid-to-liquid generator under an increasing electrical load resistance

Lesage, F. J. and Pagé-Potvin, N. *Energy Conversion and Management*, 2013, 66, 98–105.

Recent progress in thermoelectric power production using Bismuth Telluride Bi_2Te_3 semiconductor modules has revealed the potential to effectively convert large volumes of low temperature industrial waste-heat to electricity. In order to render the process more cost effective, greater understanding of the effects of external influences on the module's power output is necessary. Such an understanding would facilitate the design of thermoelectric generators which serve to exploit available waste-heat. To this end, an experimental study is performed on the most adjustable operating parameter on a thermoelectric liquid-to-liquid generator, the electrical load resistance. A test stand apparatus is built applying a temperature gradient on commercially available Bi_2Te_3 thermoelectric modules by means of an injection and a rejection of heat brought upon by counter current hot and cold liquids. The thermoelectric power production relative to an increasing electrical load is investigated by means of an analysis of experimentally measured results in which the thermal input conditions are varied. The results detail the thermoelectric characteristics of a liquid-to-liquid generator under an increasing electrical load resistance by identifying the optimal electrical load resistance for peak thermoelectric production. A correlation between peak thermoelectric power and thermal input conditions is presented as well as an investigation into the validity of electrical load matching.

13/02110 Hospital CHCP system optimization assisted by TRNSYS building energy simulation tool

Pagliarini, G. *et al. Applied Thermal Engineering*, 2012, 44, 150–158.

The feasibility study of a trigeneration plant intended to integrate the existing natural gas fired-boiler central plant serving a 714-bed hospital located in Parma, north of Italy, is presented. The electric load and the heat load for both sanitary hot water and process steam are estimated on an hourly basis from the monitored actual consumption. The space heating and the cooling loads, instead, are computed, on an hourly basis, by the building energy software tool TRNSYS, version 16, by accounting for the actual climate of the considered location. The energy analysis points out that the primary energy saving (PES) index is inadequate for sizing the combined heat and power generation system (CHP). The approach based on the second principle of thermodynamics, instead, allows to identify its optimal configuration and size, i.e. combined generation of heat, cooling and power (CHCP) with prime mover overall nominal capacity equal or higher than about 7 MW. The economic analysis confirms that the maximum annual money saving occurs with trigeneration at a prime mover overall nominal capacity of about 7 MW. At higher values the operating financial budget deteriorates because of a too low electricity selling price. At the optimal economic condition the CHCP system simple payback period is of about 15 months. The national policies supporting cogeneration have a great effect on the results of the economic analysis and beyond them cogeneration may lose its economic appeal.

13/02111 Improved performance of hybrid photovoltaic-trigeneration systems over photovoltaic-cogen systems including effects of battery storage

Nosrat, A. H. *et al. Energy*, 2013, 49, (1), 366–374.

Recent work has proposed that hybridization of residential-scale cogeneration with roof-mounted solar photovoltaic (PV) arrays can increase the PV penetration level in ideal situations by a factor of five. In regions where there is a significant cooling load PV-cogen hybrid systems could be coupled to an absorption chiller to utilize waste heat from the cogen unit. In order to investigate realistic (non-ideal) loads that such a hybrid system would need to service, a new numerical simulation called PV-trigeneration optimization model (PVTOM) was created and coupled to the results of the established Canadian hybrid residential end-use energy and emissions model. In this paper, PVTOM is applied to representative houses in select Canadian regions, which experience cooling loads, to assess the fuel utilization efficiency and reduction in greenhouse gas emissions from hybrid PV-cogen and trigen systems in comparison with conventional systems. Results of the optimization runs are provided and the efficacy of PV-cogen and PV-trigen systems is discussed. Both PV-trigen and PV-cogen systems have demonstrated to be more effective at reducing emissions when compared to the current combination of centralized power plants and household heating technologies in some regions.

13/02112 Investigation of a two stage Rankine cycle for electric power plants

Liu, B. *et al. Applied Energy*, 2012, 100, 285–294.

A two-stage Rankine cycle for power generation is presented in this paper. It is made of a water steam Rankine cycle and an organic Rankine bottoming cycle. By using an organic working fluid with higher density than water, it is possible to reduce the installation size and to use an air-cooled condenser. In order to search suitable working fluids for the application, nine potential candidates from four different organic fluid families and ammonia are tested. The performances of the two stage Rankine cycle operating with those different working fluids are evaluated. The influences of design external temperatures and the steam turbine outlet pressure on the system are analysed. Optimal points are found at different cold source temperatures and steam turbine outlet pressures for each fluid. System efficiency can also be enhanced by introducing a regenerator for some of the selected working fluids.

13/02113 Nanoheat source generated by leaky light mode within a nano-waveguide for small electrical power generator

Kamoldilok, S. and Yupapin, P. P. *Energy Conversion and Management*, 2012, 64, 23–27.

This paper presents a novel type of small electrical power generator controlled by the leaky light resonant modes or whispering gallery modes (WGMs) in a nanowaveguide, in which the nanowaveguide is designed and configured to be a nano-ring resonator. By using the Optiwave programming based on finite difference time-domain (FDTD) method, two types of InGaAsP/InP nano-ring resonators are designed and simulated, which one is a single nano-ring resonator, and the other is the double nano-ring resonator. Simulation results obtained have shown that the leaky light resonant modes can be controlled by the ring radii variations, whereas the maximum resonant peak of the single nano-ring resonator is observed at the ring radius of 1.55 μm, while the double nano-ring resonator is occurred at the inner and outer ring radii of 0.775 and 1.55 μm, respectively. The maximum peak intensities of the single nano-ring and double resonators are 1150 and 2740 W/m^2, respectively. The efficiency of the fabricated generators was calculated, in which the efficiency of a proposed micro turbine engine of 2.4 kJ is noted. Finally, the use of the leaky light mode resonant peak of the centre nano-ring resonator for nanoelectrical power generator is discussed in details.

13/02114 Online management genetic algorithms of microgrid for residential application

Mohamed, F. A. and Koivo, H. N. *Energy Conversion and Management*, 2012, 64, 562–568.

This paper proposes a generalized formulation to determine the optimal operating strategy and cost optimization scheme for a microgrid (MG) for residential application. Genetic algorithm is applied to the environmental/economic problem of the MG. The proposed problem is formulated as a non-linear constrained MO optimization problem. Prior to the optimization of the microgrid itself, models for the system components are determined using real data. The proposed cost function takes into consideration the costs of the emissions, NO_x, SO_2, and CO_2, start-up costs, as well as the operation and maintenance costs. The MG considered in this paper consists of a wind turbine, a microturbine, a diesel generator, a photovoltaic array, a fuel cell, and a battery storage. The optimization is aimed at minimizing the cost function of the system while constraining it to meet the consumer demand and safety of the system. The authors also add a daily income and outgo from sale or purchased power. The results demonstrate the efficiency of the proposed approach to satisfy the load and to reduce the cost and the emissions. The comparison with other techniques demonstrates the superiority of the proposed approach and confirms its potential to solve the problem.

13/02115 Performance assessment of a novel hybrid district energy system

Coskun, C. *et al. Applied Thermal Engineering*, 2012, 48, 268–274.

In this paper, a new hybrid system for improving the efficiency of geothermal district heating systems (GDHSs) is proposed. This hybrid system consists of biogas based electricity production and a water-to-water geothermal heat pump unit (GHPU), which uses the waste heat for both heating and domestic hot water purposes. Electricity generated by the biogas plant (BP) is utilized to drive the GDHS's pumps, BP systems and the heat pump units. Both the biogas reactor heating unit and the heat pump unit utilize the waste heat from the GDHS and use the system as a heat source. The feasibility of utilizing a hybrid system in order to increase the overall system (GDHS + BP + GHPU) efficiency is then investigated for possible efficiency improvements. The Edremit GDHS in Turkey, which is selected for investigation in this case study, reinjects 16.8 MW of thermal power into the river at a low temperature; namely at 40 °C. Such a temperature is ideal for mesophilic bacterial growth in the digestion process during biogas production. 1.45 MW of biogas based electricity production potential is obtainable from the waste heat output of the Edremit GDHS. The average overall system efficiencies through the utilization of this kind of hybridized system approach are increased by 7.5% energetically and 13% for exergetically.

13/02116 Power generation from sugarcane biomass – a complementary option to hydroelectricity in Nepal and Brazil

Khatiwada, D. *et al. Energy*, 2012, 48, (1), 241–254.

This paper discusses the complementarity between hydroelectricity and surplus electricity from sugarcane biomass-based cogeneration plants in sugarcane mills. The paper investigates opportunities and barriers in the context of governments' initiatives, institutions and prevailing regulatory frameworks in Brazil and Nepal. The paper finds that bioelectricity from cogeneration can be a good complementary option for hydroelectric power, helping foster diversification on the generation side and enhance security of electricity supply based on local resources. Bioelectricity potential from sugarcane biomass is estimated to be in the range of 209–313 GWh for Nepal and 62–93 TWh for Brazil. In Nepal, the grid connected bioelectricity can provide power for operating industries, and support local development through rural electrification. In Brazil, the biomass potential can be further enhanced through a better utilization of the biomass in the sugar-ethanol industry to balance hydropower availability. This comparative study offers a reflection on the need for better planning and policies to address the barriers which are hindering the development of bioelectricity even in places where the potential is large.

13/02117 Robust optimization of distributed generation investment in buildings

Taghipour Rezvan, A. *et al. Energy*, 2012, 48, (1), 455–463.

This paper presents a robust optimization method to determine the optimum capacity of distributed generation technologies for buildings in the face of uncertain energy demand. The model presents capacity requirements of energy system that is almost optimal for different realizations of the uncertain demand. By adjusting the penalty and degree of solution robustness parameters, the trade-off between optimality and feasibility is analysed. The optimization is carried out on three related criteria, economical, primary energy saving, and environmental performance as a multi-objective optimization. The optimum capacity of distributed generation technologies has a great effect on the performance indicators of the building. In order to show this effect, the proposed method is applied to a hospital in Iran as a case study. It is assumed that the combined heat and power (CHP) unit has both absorption and electric chiller for cooling loads, and a supplementary boiler for heating loads. In addition to them, thermal storages and renewable technologies are an option. The results show that by taking into account more solution and model robustness, the capacities of CHP and absorption chiller are increasing until they reach to their respective capacities in the solution of high scenario, while the capacities of others are decreasing. Furthermore, recommended values for the penalty and degree of solution robustness parameters are presented.

13/02118 Short-term load forecasting using SVR (support vector regression)-based radial basis function neural network with dual extended Kalman filter

Ko, C.-N. and Lee, C.-M. *Energy*, 2013, 49, (1), 413–422.

Accurate load forecasting is an important issue for the reliable and efficient operation of the power system. This paper presents a hybrid algorithm which combines support vector regression (SVR), radial basis function neural network (RBFNN), and dual extended Kalman filter (DEKF) to construct a prediction model (SVR–DEKF–RBFNN) for short-term load forecasting. In the proposed model, first, the SVR model is employed to determine both the structure and initial parameters of the RBFNN. After initialization, the DEKF is used as the learning algorithm to optimize the parameters of the RBFNN. Finally, the optimal RBFNN model is adopted to predict short-term load. The performance of the proposed approach is evaluated on real-load data from the Taipower Company, and compared with DEKF–

RBFNN and GRD-RBFNN (gradient decent RBFNN) models. Simulation results of three cases show that the proposed method has better forecasting performance than the other methods.

13/02119 Techno-economic evaluation of commercial cogeneration plants for small and medium size companies in the Italian industrial and service sector

Armanasco, F. *et al. Applied Thermal Engineering*, 2012, 48, 402–413.

The liberalization of the electricity market and the concern for energy efficiency have resulted in a surge of interest in cogeneration and distributed power generation. In this regard, companies are encouraged to evaluate the opportunity to build their own cogeneration plant. In Italy, the majority of such companies belong to the industrial or service sector; it is small or medium in size and the electric power ranges between 1 and 10 MW. Commercially available gas turbines are the less expensive option for cogeneration. Particular attention has been given to the possibility of combining an organic Rankine cycle with gas turbine, to improve the conversion efficiency. Companies have to account for both technical and economic aspects to assess viability of cogeneration. A techno-economic analysis was performed to identify, in the Italian energy market, which users can take advantage of a cogeneration plant aimed to cover at least part of their energy demand. Since electricity and thermal needs change considerably in the same sector, single product categories have been considered in the analysis. This work shows that in the industrial sector, independent of the product category, cogeneration is a viable option form a techno-economic perspective.

13/02120 The economically acceptable scenarios for investments in desulphurization and denitrification on existing coal-fired units in Bosnia and Herzegovina

Dimitrijević, Z. and Tatić, K. *Energy Policy*, 2012, 49, 597–607.

After the recent war (1992–1995) Bosnia-Herzegovina includes the two entities: the Federation of Bosnia and Herzegovina (FBiH) and the Republic Srpska (RS). Given these two entities, the country is divided politically. The country is in transition and aims to join the European Union (EU). Coal-fired plants exist in both entities, two in FBiH and two in RS. Significant investment is needed to ensure that existing coal-fired units comply with EU Directives on large combustion plants by 2017. Bosnia-Herzegovina (like some EU countries) has the chance to negotiate the position of the country with the EU with the possible outcome of getting a delay in having to fulfil the requirements for some coal-fired plants or even some exceptions. Also, there is a lack of reliable and harmonized energy data in Bosnia-Herzegovina – overall data collection on air pollutant emissions is not yet established. So, some data collection is done for the needs of this paper and by using the specific external costs, annual emissions of pollutants and cost-benefit analyses. The most acceptable scenarios for investments in desulfurization and denitrification for the existing coal-fired units in Bosnia-Herzegovina on the basis of economy and environment, not politics, is presented in the paper.

13/02121 The preparation of graphene decorated with manganese dioxide nanoparticles by electrostatic adsorption for use in supercapacitors

Zhai, D. *et al. Carbon*, 2012, 50, (14), 5034–5043.

Graphene decorated with manganese dioxide nanoparticles are prepared by electrostatic adsorption. The manganese dioxide is synthesized by a microemulsion route using the cationic surfactant hexadecyltrimethyl ammonium bromide, which dispersed in water is converted to be positively charged. The surface charge of graphene in water is negative, allowing two forms of manganese dioxide-decorated graphene to be synthesized by electrostatic adsorption: (a) free *in situ* synthesis and (b) layer-by-layer self-assembly. By electrochemical analysis, the specific capacitances of two materials are found to be about 40% and 250% larger than that of manganese dioxide. The improvement is because of the tighter contact between graphene and manganese dioxide, and the higher conductive and capacitive characteristics of graphene.

13/02122 Thermo-economic optimization of the impact of renewable generators on poly-generation smart-grids including hot thermal storage

Rivarolo, M. *et al. Energy Conversion and Management*, 2013, 65, 75–83.

In this paper, the impact of not controllable renewable energy generators (wind turbines and solar photovoltaic panels) on the thermo-economic optimum performance of poly-generation smart grids is investigated using an original time dependent hierarchical approach. The grid used for the analysis is the one installed at the University of Genoa for research activities. It is based on different prime movers: (i) 100 kWe micro gas turbine, (ii) 20 kWe internal combustion engine powered by gases to produce both electrical and thermal (hot water) energy and (iii) a 100 kWth adsorption chiller to produce cooling (cold water) energy. The grid includes thermal storage tanks to manage the thermal demand load during the year. The plant under analysis is also equipped with two renewable non-controllable generators: a small size wind turbine and photovoltaic solar panels. The size and the management of the system studied in this work have been optimized, in order to minimize both capital and variable costs. A time-dependent thermo-economic hierarchical approach developed by the authors has been used, considering the time-dependent electrical, thermal and cooling load demands during the year as problem constraints. The results are presented and discussed in depth and show the strong interaction between fossil and renewable resources, and the importance of an appropriate storage system to optimize the RES impact taking into account the multiproduct character of the grid under investigation.

13/02123 Travelling-wave thermoacoustic electricity generator using an ultra-compliant alternator for utilization of low-grade thermal energy

Yu, Z. *et al. Applied Energy*, 2012, 99, 135–145.

This paper proposes a novel concept of a travelling-wave thermoacoustic electricity generator, which employs a looped-tube travelling-wave thermoacoustic engine to convert thermal energy into acoustic power, an ultra-compliant alternator within the engine loop to extract and convert the engine acoustic power to electricity and an acoustic stub matching technique to match the alternator to the engine. In addition, a carefully designed cold heat exchanger acts as a phase shifting inertance to improve the performance. A simple model has been developed to capture and demonstrate the physics of this new concept, while the whole system has been investigated in detail numerically by using a specialized design tool DeltaEC. Based on the current concept, a prototype has been designed, constructed and tested. It uses atmospheric air as the working fluid, a commercially available audio loudspeaker as the electro-dynamic transducer, and inexpensive standard parts as the acoustic resonator. The experimental results have verified the simplified model and the numerical simulations of the practical build. The small-scale inexpensive prototype generator produced 11.6 W of electrical power, which shows the potential for developing cheap thermoacoustic electricity generators for energy recovery from waste heat sources. It is concluded that such concept could be very attractive provided that inexpensive ultra-compliant alternators based on the standard technology used in audio loudspeakers could be developed. Finally, some guidelines have been discussed and proposed for developing such alternators.

Economics, policy, supplies, forecasts

13/02124 A comparison of electricity production technologies in terms of sustainable development

Pappas, C. *et al. Energy Conversion and Management*, 2012, 64, 626–632.

The electricity production sector has currently and for the past years been dominated by fossil fuel technologies, mostly coal, oil and natural gas. This has had various environmental consequences, such as increased gaseous emissions, soil and water pollution, global warming, as well as fossil resource depletion. As a result, the need to pursue sustainable development (SD), in order to reduce dependency on fossil fuel, to achieve greenhouse gas (GHG) mitigation and to reverse the effects of climate change has currently become imperative. SD is considered to be one of the most important factors for countries' energy policy today and efforts, such as the ones materialized through the Kyoto Protocol mechanisms, are being made to promote sustainable electricity production technologies globally. Nuclear and renewable energy technologies both have the potential of contributing to the increasing global energy demands, while simultaneously lowering GHG emissions and also having a positive economic and social impact. In view of their differences and the on-going nuclear debate, this paper aims to compare specific promising and emerging nuclear and renewable energy technologies in terms of their contribution to SD and prospects for deployment. The comparison showed that each technology contributes in its own way to SD and that political decisions, individual country energy policies and public opinion will probably determine the future deployment of each energy technology.

13/02125 A simplified energy performance assessment method for existing buildings based on energy bill disaggregation

Yan, C. *et al. Energy and Buildings*, 2012, 55, 563–574.

This paper presents a simplified energy performance assessment method for existing buildings in cooling season, which is based on energy bill disaggregation and energy performance analysis. This method requests very limited building energy data and can effectively assess the energy performance at building and system levels, and disaggregate the whole-building consumption into consumptions of three groups of end-uses. This method is based on two basic energy balance principles, i.e. the electricity consumption balances at building level and the cooling energy balances between demand side and supply side of HVAC systems. An optimization algorithm is developed to establish best possible cooling energy balances by minimizing the balance residuals and therefore to disaggregate the energy consumption of different users. The performance of the proposed method was validated in two existing buildings in Hong Kong and Beijing. The results, including the disaggregated energy consumptions and the key energy performance indicators of HVAC system, agreed well with the 'measured' data in mechanical cooling months.

13/02126 An integrated approach for distributed energy resource short-term scheduling in smart grids considering realistic power system simulation

Silva, M. *et al. Energy Conversion and Management*, 2012, 64, 273–288.
The large increase of distributed energy resources, including distributed generation, storage systems and demand response, especially in distribution networks, makes the management of the available resources a more complex and crucial process. With wind based generation gaining relevance, in terms of the generation mix, the fact that wind forecasting accuracy rapidly drops with the increase of the forecast anticipation time requires to undertake short-term and very short-term re-scheduling so the final implemented solution enables the lowest possible operation costs. This paper proposes a methodology for energy resource scheduling in smart grids, considering day ahead, hour ahead and five minutes ahead scheduling. The short-term scheduling, undertaken five minutes ahead, takes advantage of the high accuracy of the very-short term wind forecasting providing the user with more efficient scheduling solutions. The proposed method uses a genetic algorithm-based approach for optimization that is able to cope with the hard execution time constraint of short-term scheduling. Realistic power system simulation, based on PSCAD®, is used to validate the obtained solutions. The paper includes a case study with a 33-bus distribution network with high penetration of distributed energy resources implemented in PSCAD®.

13/02127 Analyzing the impact of futures trading on spot price volatility: evidence from the spot electricity market in France and Germany

Kalantzis, F. G. *et al. Energy Economics*, 2013, 36, 454–463.
This paper examines the impact of the introduction of electricity futures on the spot-price volatility of the French (Powernext) and German (EEX) electricity markets, as well as the degree of their price correlation over the period 2002–2011. The working hypotheses were tested based on a bivariate VECM-GARCH model. The results indicate that the introduction of futures contracts in the French electricity market, as well as the launch of the joint futures market in these countries in 2009, has decreased spot price volatility. However, this effect was not as explicit for the German market, due to data specificities. Other interesting results are: the German market dominates and leads the long run price relationship; the impact of cooling needs on demand is greater than the impact of heating needs; there is a substantial systematic pattern of electricity prices and their respective volatilities during weekdays and holidays. Overall, results are supportive of policy making at the European Commission regarding electricity market integration.

13/02128 Combining day-ahead forecasts for British electricity prices

Bordignon, S. *et al. Energy Economics*, 2013, 35, 88–103.
This paper considers how well the approach of combining forecasts extends to the context of electricity prices. With the increasing popularity of regime switching and time-varying parameter models for predicting power prices, the multi model and evolutionary considerations that usually support the combining of simpler time series methods may be less applicable when the individual models incorporate these features. The authors address this question with a backtesting analysis on British day-ahead prices. Furthermore, given the volatility of power prices and concerns about accurate forecasting under extreme price excursions, the authors evaluate the results using various error metrics including expected shortfall. The comparisons are furthermore carefully simulated to consider model selection uncertainty in order to realistically test the value of combining as an ex ante policy. Overall, the results support combining for both accurate operational planning and risk management.

13/02129 Competition and environmental policies in an electricity sector

Chaton, C. and Guillerminet, M. L. *Energy Economics*, 2013, 36, 215–228.
This study considers the impact of competition and environmental policy (feed-in tariff versus the European Union's Emission Trading Scheme, EU ETS) on investment, CO_2 emissions and welfare in an electricity sector. The authors consider different market structures (a planner who maximizes social welfare versus duopoly) and two types of consumers (those whose behaviour depends on the weather versus those whose behaviour does not). The demand specification is innovative and takes incompressible consumption into account. Given the costs and demand functions, it was found that competition can increase CO_2 emissions, as is highlighted in a study by Mansur. In duopoly, the EU ETS seems to be the only efficient policy for reducing CO_2 emissions but also to increase the share of production based on renewable energy sources. The retained feed-in tariff policy seems to be the most expensive policy in terms of 'social welfare'. Even if this policy seems to increase 'social welfare', feed-in tariffs increase the CPSE (public service contribution), which is paid for by consumers in the form of higher electricity prices and only benefits new entrants. It is also less effective in terms of emission reduction.

13/02130 Consequences for district heating and natural gas grids when aiming towards 100% electricity supply with renewables

Kusch, W. *et al. Energy*, 2012, 48, (1), 153–159.
The increasing use of fluctuating generation plants like wind turbines and solar power systems, makes new demands on the existing power grid. These are considered to be essential for low-voltage grids. Based on the latest request from the German federal government for a progressive improvement of the heat insulation of the residential building stock the impact of a comprehensive passive house standard is analysed. Seeing that, a prediction for the future perspective of natural gas grids and district heating grids throughout Germany in 2050 has been done. Regarding this context the role of decentralized combined heat and power as well as heat pumps increases. In connection with enlarged thermal storages, their specific application can add a substantial contribution in combination with an aimed electricity supply of 100% renewable energy. The rational use of these and other supply systems is investigated within a basic virtual power plant model.

13/02131 Consumer responses to time varying prices for electricity

Thorsnes, P. *et al. Energy Policy*, 2012, 49, 552–561.
This study reports new experimental evidence of the household response to weekday differentials in peak and off-peak electricity prices. The data come from Auckland, New Zealand, where peak residential electricity consumption occurs in winter for heating. Peak/off-peak price differentials ranged over four randomly selected groups from 1.0 to 3.5. On average, there was no response except in winter. In winter, participant households reduced electricity consumption by at least 10%, took advantage of lower off-peak prices but did not respond to the peak price differentials. Response varied with house and household size, time spent away from home, and whether water was heated with electricity.

13/02132 Design of distributed energy system through electric system cascade analysis (ESCA)

Ho, W. S. *et al. Applied Energy*, 2012, 99, 309–315.
This paper presents a new numerical method called the electricity system cascading analysis (ESCA). ESCA is developed based on pinch analysis principles and useful for designing and optimizing non-intermittent power generator (biomass, biogas, natural gas, diesel, etc.) and energy storage for distributed energy generation (DEG) system. DEG system configuration for this case study comprise of solar photovoltaic (PV), biomass power generator and sodium sulfur (NaS) battery system. Application of the technique on isolated community consisting of 100 houses and daily energy demand of 845 kW h reveals that the power capacity of the biomass power generator is 39.76 kW, NaS battery is 75.8 kW, and the energy capacity of NaS battery is 157.01 kW h.

13/02133 Effects of electric vehicles on power systems in northern Europe

Hedegaard, K. *et al. Energy*, 2012, 48, (1), 356–368.
This study analyses how a large-scale implementation of plug-in hybrid electric vehicles and battery electric vehicles towards 2030 would influence the power systems of five northern European countries: Denmark, Finland, Germany, Norway and Sweden. Increasing shares of electric vehicles (EVs) are assumed; comprising 2.5%, 15%, 34% and 53% of the private passenger vehicle fleet in 2015, 2020, 2025 and 2030, respectively. Results show that when charged/discharged intelligently, EVs can facilitate significantly increased wind power investments already at low vehicle fleet shares. Moreover, due to vehicle-to-grid capability, EVs can reduce the need for new coal/natural gas power capacities. Wind power can be expected to provide a large share of the electricity for EVs in several of the countries. However, if EVs are not followed up by economic support for renewable energy technologies, coal based power will in several cases, particularly in the short term, likely provide a large part of this electricity. The effects

of EVs vary significantly from country to country and are sensitive to fuel and CO_2 price variations. The EVs bring CO_2 reductions of 1–6% in 2025 and 3–28% in 2030 while total costs are generally increased.

13/02134 Evaluation and optimization of feed-in tariffs

Kim, K.-K. and Lee, C.-G. *Energy Policy*, 2012, 49, 192–203.

Feed-in tariff (FIT) programme is an incentive plan that provides investors with a set payment for electricity generated from renewable energy sources that is fed into the power grid. As of today, FIT is being used by over 75 jurisdictions around the world and offers a number of design options to achieve policy goals. The objective of this paper is to propose a quantitative model, by which a specific FIT programme can be evaluated and hence optimized. This paper focuses on payoff structure, which has a direct impact on the net present value of the investment, and other parameters relevant to investor reaction and electricity prices. The authors combine cost modelling, option valuation, and consumer choice so as to simulate the performance of a FIT programme of interest in various scenarios. The model is used to define an optimization problem from a policy-maker's perspective, who wants to increase the contribution of renewable energy to the overall energy supply, while keeping the total burden on ratepayers under control. Numerical studies shed light on the interactions among design options, programme parameters, and the performance of a FIT programme.

13/02135 Fair electricity transfer price and unit capacity selection for microgrids

Zhang, D. *et al. Energy Economics*, 2013, 36, 581–593.

Microgrids are defined as an area of electricity distribution network that can operate autonomously from the rest of the network. In order to achieve the best economic outcomes, the participants in a microgrid can benefit from cooperation in microgrid design and operation. In this paper, a mathematical programming formulation is presented for fair, optimized cost distribution among participants in a general microgrid. The proposed formulation is based on the game-theory Nash bargaining solution approach for finding optimal multi-partner cost levels subject to given upper bounds on the equivalent annual costs. The microgrid planning problem concerning the fair electricity transfer price and unit capacity selection is first formulated as a mixed integer non-linear programming model. Then, a separable programming approach is applied to reform the resulting mixed integer non-linear programming model to a mixed integer linear programming form. The model is applied to a case study with a microgrid involving five participants.

13/02136 Fitting semiparametric Markov regime-switching models to electricity spot prices

Eichler, M. and Türk, D. *Energy Economics*, 2013, 36, 614–624.

Recently regime-switching models have become the standard tool for modelling electricity prices. These models capture the main properties of electricity spot prices well but estimation of the model parameters requires computer intensive methods. Moreover, the distribution of the price spikes must be fully specified although the high volatility of the spikes makes it difficult to check such distributional assumptions. Consequently, there are a number of competing proposals for the distribution in the spike regime. As an alternative, the authors propose a semiparametric Markov regime-switching model that leaves the distribution under the spike regime unspecified. They show that the model parameters can be estimated by employing robust statistical techniques. This presents an alternative to the existing estimation methods that are based on computer intensive numerical maximization of the likelihood function. The model in combination with the estimation framework is easier to estimate, needs less computation time and distributional assumptions. To show its advantages the authors compare the proposed model with a well-established Markov regime-switching model in a simulation study. Furthermore, the authors apply the model to log-prices for the Australian electricity market. The results are in accordance with the results from the simulation study, indicating that the proposed model might be advantageous whenever the distribution of the spike process is not sufficiently known. The results are thus encouraging and suggest the use of this approach when modelling electricity prices and pricing derivatives.

13/02137 Implementation of heat production and storage technology and devices in power systems

Romanovsky, G. and Mutale, J. *Applied Thermal Engineering*, 2012, 48, 296–300.

Implementation of heat storage devices and technologies at power generation plants is a promising way to provide more efficient use of natural energy resources. Heat storage devices can partly replace conventional heating technologies (such as direct use of fossil fuels) during peak energy demand or in the situations where heat and electricity supply and demand do not coincide and to obtain low cost heat energy which can be further transmitted to industrial, commercial and domestic consumers. This paper presents the innovative heat production and storage device and its application at conventional, nuclear and renewable power generation plants for optimization and balancing of electricity grids. The Heat Production and Storage Device is a vessel type induction-immersion heat production and storage device which produces pre-heated water under pressure for heat energy conservation. Operation of this device is based on simultaneous and/or sequential action of an inductor and an immersion heater and can be easily connected to the electricity network as a single or a three phase unit. Heat energy accumulated by the heat production and storage device can be utilized in different industrial technological processes during periods of high energy prices.

13/02138 Information communication technology and electricity consumption in emerging economies

Sadorsky, P. *Energy Policy*, 2012, 48, 130–136.

This study examines the impact of information communication technology (ICT) on electricity consumption in emerging economies. The empirical results, obtained from dynamic panel demand models, show a positive and statistically significant relationship between ICT and electricity consumption when ICT is measured using internet connections, mobile phones or the number of PCs. Long-run ICT elasticities are smaller than income elasticities but because ICT growth rates are so much higher than income growth rates, the impact of ICT on electricity demand is greater than the impact of income on electricity demand. One implication of these results is that policies designed to close the 'digital divide' between developed and developing economics by increasing the adoption of ICT in developing countries are put at odds with energy policies to reduce GHG emissions.

13/02139 Information, communication and entertainment appliance use – insights from a UK household study

Coleman, M. *et al. Energy and Buildings*, 2012, 54, 61–72.

Electricity consumption data for information, communication and entertainment (ICE) appliances (consumer electronics and ICT equipment) were collected from a sample of 14 UK households to identify patterns of appliance use. Follow-up interviews were also undertaken to explore factors that influenced the electricity consumption recorded. Results support the current consensus that ICE appliance use can be a significant electricity end-use in UK homes, often from standby loads. On average, around 23% of the households' electricity consumption was from ICE appliance use and around 7% could be attributed to standby power modes. Key appliances that contributed to the sample's average electricity consumption are identified. Inconspicuous electricity consumption from network appliances (e.g. set-top boxes, routers) is an issue of particular concern due to policy gaps. The results support technical interventions, such as the implementation of minimum energy performance standards, and other design measures. Other initiatives are required to influence householder behaviour, such as the expansion of mandatory energy labelling, improved feedback information and the use of behaviour change campaigns.

13/02140 Modeling a clean energy standard for electricity: policy design implications for emissions, supply, prices, and regions

Paul, A. *et al. Energy Economics*, 2013, 36, 108–124.

The electricity sector is responsible for roughly 40% of US carbon dioxide (CO_2) emissions, and a reduction in CO_2 emissions from electricity generation is an important component of the US strategy to reduce greenhouse gas emissions. Toward that goal, several proposals for a clean energy standard (CES) have been put forth, including one espoused by the Obama administration that calls for 80% clean electricity by 2035 phased in from current levels of roughly 40%. This paper looks at the effects of such a policy on CO_2 emissions from the electricity sector, the mix of technologies used to supply electricity, electricity prices, and regional flows of clean energy credits. The CES leads to a 30% reduction in cumulative CO_2 emissions between 2013 and 2035 and results in dramatic reductions in generation from conventional coal. The policy also results in fairly modest increases on national electricity prices, but this masks a wide variety of effects across regions.

13/02141 Price and welfare effects of emission quota allocation

Golombek, R. *et al. Energy Economics*, 2013, 36, 568–580.

This study analyses how different ways of allocating emission quotas may influence the electricity market. Using a large-scale numerical model of the Western European energy market with heterogeneous electricity producers, the authors show that different allocation mechanisms can have very different effects on the electricity market, even if the total emission target is fixed. This is particularly the case if output-based allocation (OBA) of quotas is used. Gas power production is then substantially higher than if quotas are grandfathered. Moreover, the welfare costs of attaining a fixed emission target are significantly higher. The numerical results for OBA are supported by a theoretical analysis, which offers some new results.

13/02142 Reactive power cost allocation by power tracing based method

De, M. and Goswami, S. K. *Energy Conversion and Management*, 2012, 64, 43–51.

A reactive power cost allocation method based on power tracing principle is presented here. A new solution is proposed to solve the problem of bidirectional reactive power flow to enable the application of power tracing method to reactive power flow. Reactive power supplied by the line charging capacitance is considered to be a separate reactive source and accordingly reactive load and loss are also allocated to it. Total system reactive demand including load and loss is first allocated to all the sources, viz. generators, synchronous condensers, capacitors and line charging capacitance and finally these sources are offered the revenue for supplying this power according to the pricing structure adopted. In the present work a quadratic reactive cost function is adopted for the generators and all other sources are considered to have a fixed cost per unit MVar supplied, which is calculated from the installation cost of the respective reactive power source. The work is demonstrated on IEEE standard test systems and a practical Indian grid system.

13/02143 Relationships between meteorological variables and monthly electricity demand

Apadula, F. *et al. Applied Energy*, 2012, 98, 346–356.

Electricity demand depends on climatic condition and the influence of weather has been widely reported in the past. The main purpose of this study is to analyse the effect of the meteorological variability on the monthly electricity demand in Italy. Temperature, wind speed, relative humidity and cloud cover are considered; the calendar effect is also taken into account. A multiple linear regression model based on calendar and weather related variables is developed to study the relationships between meteorological variables and electricity demand as well as to predict the monthly electricity demand up to a month ahead. The model has been extensively tested over the period 1994–2009 using different combinations of the weather related variables. Accuracies obtained are quite similar and range between 0.85% and 0.89%. Temperature turns out to be the most important variable. According to the month considered, a specific combination of the weather related variables can give the lowest mean absolute percentage error (MAPE) but differences are usually small. Good results for the summer months are obtained using heat index to calculate the cooling degree-days; the cloud cover has a major influence from February to April. When demand forecasts are performed using the predicted meteorological variables, an overall accuracy (MAPE) around 1.3% is obtained over the period 1994–2009. The proposed model clearly identifies the influence of the weather conditions on the aggregated national electricity demand.

13/02144 Security-constrained self-scheduling of generation companies in day-ahead electricity markets considering financial risk

Amjady, N. *et al. Energy Conversion and Management*, 2013, 65, 164–172.

In this paper, a new security-constrained self-scheduling framework incorporating the transmission flow limits in both steady state conditions and post-contingent states is presented to produce efficient bidding strategy for generation companies (GENCOs) in day-ahead electricity markets. Moreover, the proposed framework takes into account the uncertainty of the predicted market prices and models the risk and profit trade-off of a GENCO based on an efficient multi-objective model. Furthermore, unit commitment and inter-temporal constraints of generators are considered in the suggested model converting it to a mixed-integer programming optimization problem. Sensitivity of the proposed framework with respect to both the level of the market prices and adopted risk level is also evaluated in the paper. Simulation results are presented on the IEEE 30-bus and IEEE 118-bus test systems illustrating the performance of the proposed self-scheduling model.

13/02145 Simulating energy use and energy pricing in buildings: the case of electricity

Kouveletsou, M. *et al. Energy and Buildings*, 2012, 54, 96–104.

The paper presents a methodology that has been developed and implemented for the simulation of electricity use (kWh) as well as electricity pricing (c€/kWh) in buildings. In the simulation, electricity pricing has been treated as dependent on electricity use as energy pricing tariffs usually discriminate between specific electricity consumption zones, time periods, etc. Pricing and electricity use, together, may then provide an estimation of the building electric energy cost (€). The simulation runs on an hourly resolution allowing to highlight some potential wasteful and costly practices in energy use and management and providing insight to user behaviour, which has been a key driver for its development. The key aspects of the simulation approach are presented and its use is demonstrated in two different buildings in Greece and Italy. The methodology is now adapted to allow for neural network based, real time training, which will also be briefly introduced.

13/02146 The Chinese electricity access model for rural electrification: approach, experience and lessons for others

Bhattacharyya, S. C. and Ohiare, S. *Energy Policy*, 2012, 49, 676–687.

The economic and infrastructural disparities between the rural and urban communities of most developing countries in general and in terms of energy access in particular are quite glaring. China presents a good example of a developing country that has successfully embarked on rural electrification projects over the last few decades and achieved a great feat of almost 100% electrification rate. The purpose of this paper is to find out how China has achieved this feat, how China's rural energy projects were financed and whether China provides lessons for other countries to follow? The above questions are examined through an extensive literature review and the paper finds that unlike many other countries following the top-down approach to rural electrification, China has preferred to use a phased development through a bottom-up approach where local resources, and village level development and empowerment played an important role. While the state provided the overall guidance and financial support, the integrated rural development approach has produced local-level solutions that are subsequently integrated to produce an alternative development pathway. Strong government commitment, active local participation, technological flexibility and diversity, strong emphasis on rural development through agricultural and industrial activities and an emphasis on capacity building and training have also played an important role in the success. However, despite achieving the universal access objective, China still faces a number of issues related to rural electricity use, especially in terms of regional use patterns, long-term sustainability of supply and commercial operation of the systems. The Chinese model could serve as an inspiration for other developing countries trying to ensure universal electricity access.

13/02147 The electricity prices in the European Union. The role of renewable energies and regulatory electric market reforms

Moreno, B. *et al. Energy*, 2012, 48, (1), 307–313.

The European Union (EU) electricity market has been gradually liberalized since 1990s. Theoretically, competitive markets should lead to efficiency gains in the economy thus reducing electricity prices. However, there is a controversial debate about the real effects of the electricity liberalization on electricity prices. Moreover, the increased generation of electricity from renewable energies RES-E (Electricity from Renewable Energy Sources) is also integrated in wholesale market reducing wholesale prices, but the final effect over household prices is not clear. In order to contribute to this debate, this paper provides an empirical investigation into the electricity prices determinants. Econometric panel models were developed to explore the relationship between the household electricity prices and variables related to the renewable energy sources and the competition in generation electricity market. More specifically a panel data set provided by Eurostat and covering 27 European Union (EU) countries during the period 1998–2009 was used. The results suggest that electricity prices increase with the deployment of RES-E and with the expansion of greenhouse gas emissions produced by energy industries – as a EU CO_2 emission trading scheme exists. Results also reveal that a country's characteristics can affect household electricity prices.

13/02148 The impact of electrified transport on local grid infrastructure: a comparison between electric cars and light rail

Grenier, A. and Page, S. *Energy Policy*, 2012, 49, 355–364.

This study examines the impact on the local electricity grid should electric vehicles (EVs) or a light rail transit (LRT) system be introduced to the city of Christchurch, New Zealand. Spatial analysis highlighted that EV owners would not be evenly distributed throughout the city, and the initial stages of a proposed LRT network would cover only a limited area. Therefore, a few local power substations would have to provide the majority of additional power for both electric transport modes. Without management of EV charging patterns, one of the local substations would be overloaded if more than 2.6% of the Christchurch light vehicle fleet were EVs. The power demand from a LRT system would not overload the local grid given current demand levels. However several substations would need an upgrade 4 years earlier than current plans. A comparative analysis shows that despite the power demand from an EV fleet being higher than the demand from a LRT system (on an equal passenger kilometre per day basis), demand side management methods would allow shifting EV charging off peak time whereas a LRT system would still contribute significantly more to peak load.

13/02149 The scenario analysis on CO_2 emission mitigation potential in the Turkish electricity sector: 2006–2030

Özer, B. *et al. Energy*, 2013, 49, (1), 395–403.

A scenario analysis method based on the long-range energy alternatives planning system (LEAP) model was used for an analysis of reduction of emissions in the electricity sector of Turkey. Business as usual (BAU) and mitigation scenarios address the simulations from different approaches. Each scenario represents a different development path which is possible in Turkey's electricity sector due to various policies. The simulations are applied until the year 2030, while 2006 is set as the base year. Carbon dioxide (CO_2) emissions will rise significantly under the baseline scenario. In the mitigation scenario, electricity-related CO_2 emissions grew by 5.8% annually between 2006 and 2030, while electricity output grew at an average of 6.6% per annum in this period. Comparison between the CO_2 emissions suggested by the scenarios presents the mitigation potential of the electricity sector. The mitigation scenario is characterized by its aggressive greenhouse gas control policies and can achieve mitigation ratio of 17.5% over the simulation period. The cumulative CO_2 emission reduction between the BAU and mitigation scenarios from 2006 to 2030 is 903 million tons. Additionally, CO_2 emission intensity has decreased by 18.4% in 2030 compared to 2006.

13/02150 The use of occupancy space electrical power demand in building cooling load prediction

Leung, M. C. *et al. Energy and Buildings*, 2012, 55, 151–163.

This paper presents an investigation into the use of occupancy space electrical power demand to mimic occupants' activities in building cooling load prediction by intelligent approach. The occupancy space electrical power demand is obtained from an intelligent networked building power monitoring system. It works as a prototype advanced metering infrastructure – a key feature in smart grid technology. The artificial neural network model adopted is the Levenberg–Marquardt algorithm. The input parameters include the usual external climatic data, hour-type/day-type and pretreated air unit operation schedule, and the occupancy space electrical power demand. The output is the electrical power demand of the building cooling system. Simulation studies are conducted for a university building in Hong Kong. The 2010 and 2011 yearly data is used to conduct simulations. The performance indices used in evaluating the prediction performance are the coefficient of correlation (R), coefficient of variation (CV) and mean absolute percentage error (MAPE). It is demonstrated that with the use of occupancy space electrical power demand as one of the model input parameters, the prediction accuracy of the building cooling load model can be improved. In summer season, the best MAPE and CV is 4.494% and 5.808%, respectively, for hourly prediction, and is 1.935% and 2.345%, respectively, for daily prediction. On daily peak cooling load prediction in summer season, the best MAPE and CV is 2.313% and 2.862%, respectively. It is found that the variability in the prediction is modest in summer season.

13/02151 Valuing the carbon exposure of European utilities. The role of fuel mix, permit allocation and replacement investments

Koch, N. and Bassen, A. *Energy Economics*, 2013, 36, 431–443.

This paper assesses the carbon exposure of European electric utilities covered by the European Union Emissions Trading System (EU ETS). First, the authors rely on an asset pricing model to empirically determine the effect of carbon price risks on firm-specific cost of capital for a sample of 20 European utility stocks during the period 2005–2010. Second, they employ a discounted cash flow framework to simulate carbon-adjusted equity values for three selected utilities and their investment strategies from 2009 to 2020. The authors show that company-specific carbon risks are asymmetrically distributed to a few utility firms: while for the great majority of power producers carbon price movements are not a relevant risk factor, the authors find that utilities with an extremely high-emitting fuel mix bear significant risk premiums for carbon which translate to higher cost of capital and a loss of equity value. In contrast, they find no evidence that low-emitting utilities benefit from reduced capital costs. The authors further reveal that, in addition to the firm's fuel mix, permit allocation rules and replacement investment decisions in terms of fuel technology choice are the driving forces behind the carbon exposure of the utilities. The carbon-related loss of equity value is substantially reduced by implementing an investment strategy directed towards a carbon-free generation mix. The derogations from full permit auctioning in eastern European member states provide insurance against carbon risks of utilities.

13/02152 Zero peak housing: exploring the possibility of eliminating electrical draws from houses during periods of high demand on the electrical grid

Pietila, A. *et al. Building and Environment*, 2012, 58, 103–113.

Residential buildings constitute one of the largest demands for electricity. Although the contribution of air-conditioning to total energy use is quite small in many climates, this end-use can place a disproportionate demand upon the central electrical generation, transmission, and distribution system, particularly in the late afternoon of hot summer days. Even in some heating dominated climates, these can be the times of system-wide peak demand, and it is common for electrical systems (such as in Ontario, Canada) to meet marginal demands during these peak periods using generators fired by GHG-intensive fuels (coal and natural gas). The viability of achieving a zero peak house (ZPH) – a house that draws no electricity from the grid during system-wide peak periods – has been assessed via detailed building performance simulations using a case study house based on a tract-built design in Toronto, Ontario, Canada. It was found that 41–51% of the goal of eliminating electricity consumption during the summer Ontario on-peak period (11h00 to 17h00 during weekdays from 1 May through 31 October) could be achieved through a combination of architectural, control, efficiency, and occupant behaviour measures. It was also found that the remaining demand for electricity could be completely eliminated using realistically sized photovoltaic and battery systems for on-site generation and storage of electricity.

07 STEAM RAISING

Boiler operation/design

13/02153 A novel technique for measuring the kinetics of high-temperature gasification of biomass char with steam

Woodruff, R. B. and Weimer, A. W. *Fuel*, 2013, 103, 749–757.

Solar thermal gasification of biomass is a promising technology that allows for operation at high temperature without burning a large portion of the biomass feedstock. Additionally, the process allows for solar energy to be stored and transported in chemical form. In order to design efficient solar reactors, a kinetic rate expression for high-temperature steam gasification is needed. Various methods have been used to measure the steam gasification rate of coal and biomass char at temperatures up to 1000 °C. These conventional techniques often fail to collect accurate kinetic data at temperatures above 1000 °C due to heat and mass transfer resistance, and the time constants associated with the analysis system. This study considers a novel kinetics measurement technique based on a modified fixed bed and data collected solely from a gas flow meter. The technique was used to collect kinetic rate data for switchgrass char over a range of reaction conditions between 1000 and 1150 °C. An empirical expression to predict the kinetic rate as a function of the degree of conversion, temperature, steam concentration, and hydrogen concentration was developed. The random pore model was used to predict the reaction rate as a function of conversion, and the initial kinetic rate was fit using a Langmuir–Hinshelwood type expression.

13/02154 Evaluation of overfire air behavior for a down-fired 350 MW_e utility boiler with multiple injection and multiple staging

Kuang, M. *et al. Applied Thermal Engineering*, 2012, 48, 164–175.

In situ measurements on a down-fired pulverized-coal 350 MW_e utility boiler revealed that, aside from particularly high NO_x emissions, an asymmetric combustion phenomenon characterized by gas temperatures near the front wall being clearly higher than those near the rear wall, had developed in the furnace. A deflected flow field, obtained by cold airflow experiments within a small-scale model of the furnace, accounts for this asymmetric combustion. With focus on these problems, a new combustion technology based on a concept of multiple-injection and multiple-staging has been developed. To establish optimal overfire air (OFA) ratio settings with this technology, cold airflow experiments were conducted recording aerodynamic field measurements within a small-scale model of the boiler at five different OFA ratio settings, i.e. 0%, 10%, 15%, 20% and 25%. For all except the highest setting, well-formed symmetric flow fields appeared in the lower furnace and the furnace throat. Increasing the OFA ratio in 0–20% raised the reach of the OFA flow in the furnace throat without incurring adverse effects in the overall flow field. At the highest setting, a deflected flow field developed not only in the lower furnace but also in the furnace throat. To establish a symmetric flow field, along with an appropriate penetration depth of the OFA flow, an optimal setting of 20% was found for the OFA ratio.

13/02155 Experimental simulation of Na and Cl hideout in steam generator crevices

Bahn, C. B. *et al. Nuclear Engineering and Design*, 2012, 250, 156–166.
Some types of corrosion of steam generator tubes involve impurity concentration in a gap (‘crevice’) between the tubes and supporting structures or sludge piles. The purpose of this work is to characterize the concentration of sodium and chlorine in the crevices using a crevice simulator in a model boiler. Magnetite-packed crevices with lower permeability and thermal conductivity are more appropriate for the simulation of actual steam generator crevices than diamond-packed crevices. A radial pH gradient was observed in the magnetite-packed crevice that was also reported in an earlier work. The crevice pH near the tube wall appears to be alkaline initially due to the volatility effect of Cl. As time progresses, the crevice pH becomes neutralized and even acidic because of delayed preferential Cl concentration. This is enabled by a reduced boiling rate near the tube wall due to the presence of a Na-rich liquid film. During one fuel cycle, the crevice chemistry would be in a transient condition rather than a steady state because of the low impurity exposure (∼10 ppm h) unless some impurities remain after each fuel cycle.

13/02156 Numerical simulation of a small-scale biomass boiler

Collazo, J. *et al. Energy Conversion and Management*, 2012, 64, 87–96.
This paper presents a computational fluid dynamic simulation of a domestic pellet boiler. Combustion of the solid fuel in the burner is an important issue when discussing the simulation of this type of system. A simplified method based on a thermal balance was developed in this work to introduce the effects provoked by pellet combustion in the boiler simulation. The model predictions were compared with the experimental measurements, and a good agreement was found. The results of the boiler analysis show that the position of the water tubes, the distribution of the air inlets and the air infiltrations are the key factors leading to the high emission levels present in this type of system.

13/02157 Process integration of near-neutral hemicellulose extraction in a Scandinavian kraft pulp mill – consequences for the steam and Na/S balances

Lundberg, V. *et al. Applied Thermal Engineering*, 2012, 43, 42–50.
While in a conventional kraft pulp mill, most of the hemicellulose and lignin fraction of the wood is burned in the recovery boiler to produce steam, in a biorefinery it can partially be used to produce added-value products. In this paper, the most important consequences of integrating a bioethanol production plant with a model pulp mill are presented in terms of steam and Na/S balances. The model mill represents an average Scandinavian hardwood kraft pulp mill, and the bioethanol plant is based on the ‘near-neutral’ hemicellulose pre-extraction method. Regarding the steam balance, a comprehensive heat integration study is performed. Implementing hemicellulose extraction increases the net steam demand by 48 MW. However, process integration at the mill and the bioethanol plant individually leads to significant steam savings, and a corresponding net increase of steam by only 3 MW. Additional steam savings can be achieved if the total integration of the two processes (between the pulp mill and the bioethanol plant) is considered (3 MW), resulting in a biorefinery with no increase of steam demand. As regards the Na/S balance, it is shown that green liquor export from the mill to the bioethanol plant results in severe disruptions in the sodium and sulfur balance of the mill. Different attempts to solve this problem are discussed, but found to be very costly and/or negatively affect the water and steam balance of the mill.

13/02158 Research on the elliptic aerodynamic field in a 1000 MW dual circle tangential firing single furnace ultra supercritical boiler

Sha, L. *et al. Energy*, 2012, 46, (1), 364–373.
An IFA300 constant temperature anemometer system is adopted to perform cold air experiments on a scale model of a dual circle tangential firing single furnace ultra-supercritical boiler to investigate the causes and influencing factors of jet deviation in the furnace, which is the main cause of the elliptical aerodynamic field. The elliptic aerodynamic field could cause heat imbalance in the burner zone, in which case high-temperature corrosion and slagging might happen on the high-temperature furnace wall. Theoretical derivations and analysis have been carried out before any experimental studies, and an equation determining the influencing factors of the jet deviation has been established. The experimental results agree well with the equation. The jet deviation becomes more problematic when the velocity ratio of the impacting jet and the impacted jet increases from 0.85 to 1.30. A reduction in the distance from the impacting position to the root of the impacted jet also increases the jet deviation as well as the angle between the impacting jet and impacted jet. The results of the theoretical analysis and experiments provide some transformations within the boiler that could be adopted to avoid the formation of the oblique ellipse flow field.

13/02159 The influence of calcite loading on producer gas composition and tar concentration of radiata pine pellets in a dual fluidised bed steam gasifier

Saw, W. L. and Pang, S. *Fuel*, 2012, 102, 445–452.
This study has investigated the influence of calcite loading on the producer gas composition and the tar concentrations on a $100\,kW_{th}$ dual fluidized bed (DFB) steam gasifier. In the experiments, wood pellets of radiata pine were used as the feedstock and the operating temperature in the bubbling fluidized bed reactor (BFB) was set at 710–750 °C while that in the fast fluidized bed reactor (FFB) was controlled at 800 °C. In the first part of the experiments, the calcite loading was varied at 0%, 50% and 100% at constant steam to biomass (S/B) ratio of $0.8\,kg/kg_{dry}$. In the second part of the experiment, the influence of S/B ratio was examined at 50% and 100% calcite loadings. The present study has concluded that the ratio of H_2/CO can be varied from 0.9 to 4.2 by increasing the calcite loading and the S/B ratio only at 100% calcite loading. In addition, the total tar concentration decreased exponentially from 5.0 to $0.7\,g/N\,m^3$ with the calcite loading. This method provides the flexibility to meet the required H_2/CO in target downstream applications. However, the disadvantage of increasing calcite loading was that the attrition rate increased exponentially from 0.5% at 0% loading to 4.1 kg/h at 100% loading. The tar reduction from 0% to 50% calcite loading was found to be higher than that from 50% to 100% calcite loading. This could be mainly due to the suppressing effect of high partial pressure of H_2 on the steam reforming of those tar compounds.

08 COMBUSTION

Burners, combustion systems

13/02160 Analysis of biomass and sewage sludge devolatilization using the distributed activation energy model

Soria-Verdugo, A. *et al. Energy Conversion and Management*, 2013, 65, 239–244.
The thermal decomposition of biomass (pine pellets) and sewage sludge was studied using thermogravimetric analysis under an inert atmosphere and the distributed activation energy model (DAEM) was employed. The activation energy and the frequency factor that characterize the kinetics were determined for both samples. A simplification of the process for prediction of devolatilization curves was proposed, evaluating its validity for both cases. The simplified method was found to combine both simplicity and low deviations with experimental data.

13/02161 Analysis of soot particles derived from biodiesels and diesel fuel air-flames

Merchan-Merchan, W. *et al. Fuel*, 2012, 102, 525–535.
Soot particles derived from canola methyl ester (CME), soybean methyl ester (SME), a 50% mixture composed of soybean methyl ester (SME) and animal fats (AF), and diesel fuel have been studied using a wick-generated open-air laminar diffusion flame operating at atmospheric pressure. The particles were collected directly from inside the flame volume at different axial locations using the thermophoretic sampling technique and were analysed using transmission electron microscopy (TEM) and high resolution TEM (HR-TEM). Interestingly, the results show that carbon particulates produced from several tested biodiesels have diameters significantly smaller than those produced in diesel fuel under the same experimental conditions. Within the tested biofuels, the soot from SME had the largest primary particle diameter followed by B50 SME/B50 AF, with CME having the smallest primary particle diameter. Further studies of the soot particle nanostructure were also conducted using a HR-TEM imaging technique. It was found that the soot derived from biodiesel has a highly graphitic shell–core arrangement compared to diesel soot which exhibits far less graphitic structure as it consists of short, disconnected and not concentrically oriented graphene segments.

13/02162 CFD modelling of air-fired and oxy-fuel combustion in a large-scale furnace at Loy Yang A brown coal power station

Al-Abbas, A. H. *et al. Fuel*, 2012, 102, 646–665.

Oxy-fuel combustion technique is a viable option to reduce several types of greenhouse gases (GHGs) emissions from the pulverized coal (PC) combustion systems. In this paper, a computational fluid dynamics (CFD) modelling study has been developed in order to investigate the Victorian brown coal combustion in a 550 MW utility boiler under the air-fired (reference case) and three oxy-fuel-fired scenarios. The reference firing case was modelled based on the operating conditions of Loy Yang A power plant located in the state of Victoria, Australia. While Chalmers' oxy-fuel combustion approach was selected for the present oxy-fuel combustion simulations, which referred to as OF25 (25 vol.% O_2), OF27 (27 vol.% O_2), and OF29 (29 vol.% O_2). User-defined functions (UDFs) were written and incorporated into the CFD code to calculate the following mathematical models: the PC devolatilization, char burnout, multi-step chemical reactions, mass and heat transfer, carbon in fly-ash, and NO_x formation/destruction. A level of confidence of the CFD model was achieved validating four different parameters of the conventional combustion case, as well as the previous preliminary CFD studies that conducted on a 100 kW unit firing propane and lignite under oxy-fuel combustion environments. The numerical results of OF29 combustion condition were considerably similar to the reference firing results in terms of gas temperature levels and radiative heat transfer relative to the OF25 and OF27 combustion cases. This similarity was due to increasing the residence time of PC in the combustion zone and O_2-enriched in feed oxidizer gases. A significant increase in the CO_2 concentrations and a noticeable decrease in the NO_x formation were observed under all oxy-fuel combustion scenarios. The combustion chemistry was adopted in these investigations in order to capture the effects of O_2 concentrations and gas temperatures on the CO/CO_2 production rate and equilibrium between H_2 and H_2O in the combustion zone. Also, the use of O_2-enriched atmospheres during oxy-fuel-fired cases was slightly enhanced the carbon burnout rate. These predicted results were reasonably consistent with the experimental investigations and numerical modelling found in the literature. This study of Victorian brown coal oxy-fuel combustion in a large-scale tangentially-fired boiler is important prior to its implementation in real-life.

13/02163 Characterization of pyrolytic products obtained from fast pyrolysis of chromated copper arsenate (CCA)- and alkaline copper quaternary compounds (ACQ)-treated wood biomasses

Kim, Y.-J. *et al. Journal of Hazardous Materials*, 2012, 227–228, 445–452.

In this study, chromated copper arsenate-treated wood (CCA-W) and alkaline copper quaternary compounds-treated wood (ACQ-W) were subjected to fast pyrolysis at 500 °C for ca. 2 s to produce bio-oil and char. The physicochemical properties of the pyrolytic products as well as the distribution of heavy metals – arsenic, copper and chrome – during fast pyrolysis were investigated. The water content, viscosity, pH and higher heating value (HHV) of bio-oil from CCA-W were 24.8 wt%, 13.5 cSt, 2.1 and 16 MJ/kg, respectively, whereas those of bio-oil from ACQ-W were 27.9 wt%, 16 cSt, 3.0 and 14.1 MJ/kg, respectively. The yields of bio-oil from CCA-W and ACQ-W were 43.3% and 46.6%, respectively, significantly lower than that of control (61.6%). In the pyrolytic products of CCA-W, the concentrations of arsenic, copper and chromium were determined to be 36.4, 74.0 and 75.4 wt% in char, respectively, 34.5, 10.3 and 9.0 wt% in bio-oil, respectively, and 29.0, 15.7 and 15.5 wt% in gas, respectively. In addition, most of the copper appeared in the char (98.8 wt%) and only a trace amount of copper was detected in the bio-oil (0.2 wt%) produced by ACQ-W.

13/02164 Chemical-looping combustion of solid fuels – operation in a 10 kW unit with two fuels, above-bed and in-bed fuel feed and two oxygen carriers, manganese ore and ilmenite

Linderholm, C. *et al. Fuel*, 2012, 102, 808–822.

Chemical-looping combustion (CLC) is a combustion concept with inherent separation of CO_2. The process uses a solid oxygen carrier, which consists of metal oxide, to transfer the oxygen from air to fuel. The chemical-looping combustor used in the present experiments features two interconnected fluidized beds; a fuel reactor (FR) and an air reactor (AR). In the FR, fuel is gasified with steam whereupon gasification products react with the oxygen carrier to form, ideally, CO_2 and H_2O. This study concerns CLC of solid fuels in a continuously operating 10 kW unit using two natural ores as oxygen carrier: (a) ilmenite, an iron–titanium mineral and (b) a manganese ore containing smaller amounts of Fe, Al and Si. The fuel feed was redesigned in order to increase contact between oxygen carrier and fuel. The new in-bed fuel feed was found to significantly improve gas conversion, mainly caused by increased contact between the oxygen carrier and volatile gases released in the fuel chute. Two fuels were used to evaluate the effect of fuel feed; a bituminous coal and a pet coke. The in-bed fuel feed was used when ilmenite and manganese ore were compared. The use of a manganese ore as oxygen carrier was shown to significantly enhance the rate of char gasification and also improve gas conversion. A concern with the manganese ore is the large production of fines.

13/02165 Combustion of alternative fuels in vortex trapped combustor

Ghenai, C. *et al. Energy Conversion and Management*, 2013, 65, 819–828.

Trapped vortex combustor represents an efficient and compact combustor for flame stability. Combustion stability is achieved through the use of cavities in which recirculation zones of hot products generated by the direct injection of fuel and air are created and acting as a continuous source of ignition for the incoming main fuel–air stream. Computational fluid dynamics analysis was performed in this study to test the combustion performance and emissions from the vortex trapped combustor when natural gas fuel (methane) is replaced with renewable and alternative fuels such as hydrogen and synthetic gas (syngas). The flame temperature, the flow field, and species concentrations inside the vortex trapped combustor were obtained. The results show that hydrogen enriched hydrocarbon fuels combustion will result in more energy, higher temperature (14% increase when methane is replaced with hydrogen fuels) and NO_x emissions, and lower CO_2 emissions (50% decrease when methane is replaced with methane/hydrogen mixture with 75% hydrogen fraction). The NO_x emission increases when the fraction of hydrogen increases for methane/hydrogen fuel mixture. The results also show that the flame for methane combustion fuel is located in the primary vortex region but it is shifted to the secondary vortex region for hydrogen combustion.

13/02166 Effect of exhaust confinement and fuel type upon the blowoff limits and fuel switching ability of swirl combustors

Abdulsada, M. *et al. Applied Thermal Engineering*, 2012, 48, 426–435.

The use of swirl burners with premixed hydrogen–methane fuel blends is a promising technology for low-emission power generation. Utilization of hydrogen containing fuel mixtures can result in low-emission levels, but it is well known that there are many difficulties, primarily because of the very high laminar and turbulent flame speeds of hydrogen. Problems such as blowoff and flashback limits are extremely important where fuel flexibility is required. In this study, a generic swirl combustor at Cardiff University's GTRC is utilized to investigate blow-off and the ability of the premixed combustor to switch fuels whilst still maintain the same thermal load, for a range of alternative hydrogen based fuel mixtures in configurations where the confinement is representative of gas turbine practice. This complements previous work on the same generic combustor, where the focus was entirely on flashback limits. Ideally to achieve fuel switching or dual fuelling for nominally similar combustor geometries, the operating points for pure hydrogen and natural gas should lie in an operational regime between the blow-off and flashback limits of both fuels. Normal concepts of equivalence ratio matching need modification to allow for the varying stoichiometric requirements of different fuel mixtures and the associated differences in their heating values. Here heating input from the various fuels as a function of mass flow is used to compare their ability to operate in the same operational, fuel lean regime of the premixed combustor. In practice this is extremely difficult; however, fuel switching/dual fuelling is possible in the swirl burner with certain fuel blends (where the hydrogen content is limited). The results demonstrate and quantify improvements in blow-off limits for hydrogen-enriched methane flames. Moreover, for all geometrical configurations considerably improved blow-off characteristics were observed for the confined cases in contrast to the unconfined cases. This data offers a significant insight to burner manufacturers aiming to use swirl combustors with hydrogen-containing alternative fuels.

13/02167 Effects of exhaust gas recirculation on the thermal efficiency and combustion characteristics for premixed combustion system

Yu, B. *et al. Energy*, 2013, 49, (1), 375–383.

In this research, a boiler in a premixed combustion system used to achieve exhaust gas recirculation was investigated as a way to achieve high thermal efficiencies and low pollutant emissions. The effects of various exhaust gas recirculation (EGR) ratios, equivalence ratios and boiler capacities on thermal efficiency, NO_x and CO emissions and the flame behaviour on the burner surface were examined both experimentally and numerically. The results of the experiments showed that when EGR was used, the NO_x and CO concentrations decreased and the thermal efficiency increased. In the case of a 15% EGR ratio at an equivalence ratio of 0.90, NO_x concentrations were found to be smaller than for the current operating condition of the boiler, and the thermal efficiency was approximately 4.7% higher. However, unlike NO_x concentrations, although the EGR ratio was increased to 20% at an equivalence ratio of 0.90, the CO concentration was higher than in the current operating condition of the boiler. From the viewpoint of burner safety, the red glow on the burner surface was noticeably reduced when EGR was used. These results confirmed that the EGR method is advantageous from the standpoint of reducing emission concentrations and ensuring burner safety.

13/02168 Effects of particle characteristics on flame propagation behavior during organic dust explosions in a half-closed chamber

Gao, W. *et al. Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 993–999.

To reveal the effects of particle characteristics on the mechanisms of flame propagation during organic dust explosions clearly, three long chain monobasic alcohols which are solids at room temperature and have similar physical–chemical properties were chosen to carry out experiments in a half-closed small chamber. A high-speed video camera was used to record the flame propagation process and to obtain the direct light emission photographs. Flame temperature was detected by a fine thermocouple. Based on the experimental results above, analysis was conducted on flame propagation characteristics and temperature profiles of organic particle cloud. As a result, it was found that the particle materials, especially volatility, strongly affected the flame propagation behaviour. Particle concentration also affects the combustion zone propagation process significantly. With increasing the particle concentration, the maximum temperature of the combustion zone increases at the lower concentration, reaches a maximum value, and then decreases at the higher concentration. The propagation velocity of the combustion zone has a linear relationship with the maximum temperature, which implies conductive heat transfer is dominant in the flame propagation process of the three different volatile dusts.

13/02169 Experimental investigation of flame pattern transitions in a heated radial micro-channel

Fan, A. *et al. Applied Thermal Engineering*, 2012, 47, 111–118.

Flame pattern transitions of CH_4/air mixture were experimentally investigated in a radial micro-channel. These transitions were triggered by a variation in the mixture equivalence ratio or inlet mixture velocity. The transition processes were recorded with a high-speed digital video camera. From the movies, it is shown that the mechanisms responsible for these transitions could be classified into two: (1) transitions from a stable circular flame to a travelling flame, and from a travelling flame to single or double Pelton-like flames were due to local extinction in the flame front, and (2) transition from an unstable circular flame to a spiral-like flame was due to local splitting of the flame front. Numerical simulation of the isothermal flow demonstrated that flow field is symmetric and steady when the inlet velocity is small, but it grows asymmetric and unstable at large inlet velocities. The asymmetric and unstable flow field is expected to be the possible reason for the local splitting of flame front. On the other hand, flame is noted to be quenched near the top wall surface. These two reasons are expected to induce the transition from an unstable flame to a rotating spiral-like flame.

13/02170 Fast pyrolysis of microalgae in a falling solids reactor: effects of process variables and zeolite catalysts

Campanella, A. and Harold, M. P. *Biomass and Bioenergy*, 2012, 46, 218–232.

Non-catalytic and catalytic pyrolysis of microalgae were carried out to generate an organic liquid fuel precursor. The impacts of several process variables on the fast pyrolysis in a falling solids reactor are reported, including temperature, particle size, flow rate, and atmosphere (N_2, H_2O and CO_2). Experiments were carried out with duckweed as the biomass to provide some comparison. The speciated organic phase product data were classified according to the different compound types including hydrocarbons, alcohols, oxygenates, and nitrogenates. *In situ* catalytic pyrolysis produced an organic phase with an increased fraction of hydrocarbons and decreased fraction of oxygenates, evidence for carbon removal chemistries such as decarboxylation and decarbonylation. The non-catalytic pyrolysis gave the highest total liquid yield while catalytic pyrolysis resulted in the highest yield of the desired hydrocarbon fraction. A comparison of four exchanged ZSM-5 catalysts (H-, Fe-, Cu-, and Ni-) indicates that the protonated zeolite provided the largest enhancement among the catalysts of the liquid product yield and composition: H-ZSM-5 increased the yield of the hydrocarbon fraction in the organic phase from 21% to 43%, a 100% relative increase, and exhibited the least coking. The effects of biomass weight hourly space velocity, and comparisons between H-ZSM5 powder and monolithic catalysts are also reported. The implications of the findings for the conversion of microalgae to liquid fuels are discussed.

13/02171 Fast solution of direct and inverse design problems concerning furnace operation conditions in steel industry

Martín, E. *et al. Applied Thermal Engineering*, 2012, 47, 41–53.

In this paper a fast numerical simulation tool able to accurately predict steel products heating in an industrial furnace is developed. This prediction tool is set up in two steps: first, a complete finite element model of the furnace is built up, and then a surrogate model based on the information extracted from the results of the previous one (alternatively, results of experimental tests could also be used) is developed. More precisely, the surrogate model developed in the second step is based on the computation of a numerical simulation database (using the finite element model) and the use of a high order singular value decomposition and interpolation techniques. Errors in the heating prediction provided by the surrogate model are comparable to the corresponding errors in the finite element model. Computation time instead is dramatically reduced: in the validation case presented in this paper (corresponding to a heat treatment furnace), computation time of the heating prediction in a desktop computer drops from around 2 h for the complete finite model to a few milliseconds for the surrogate model. The developed fast prediction tool is then applied to solve some design problems. Among them, a problem concerning the design of operation conditions able to minimize a functional involving the quality of the workpiece heat treatment and the fuel consumption is solved.

13/02172 Heat transfer optimization of an impinging port-array inverse diffusion flame jet

Dong, L. L. *et al. Energy*, 2013, 49, (1), 182–192.

This paper is an experimental study on the heat transfer optimization of an innovative inverse diffusion flame (IDF) characterized by a central air jet surrounded by an array of fuel jets for impingement heating. It is found that the diameter ratio between air and fuel ports (d_a/d_f) exerts significant influence on the impingement heat transfer performance via changing the hydrodynamics and the thermal structure of the IDF. The effects of the overall equivalence ratio (Φ), the burner-to-plate distance (H), and the air jet Reynolds number (Re_a), on the local and average heat fluxes, are investigated and compared between IDFs with different d_a. Under the same air flow rate ($\dot{Q}_a$) and fuel flow rate ($\dot{Q}_f$), it is found that the IDF jet with smaller d_a produces higher maximum heat flux (q'_{max}) and average heat flux in the impingement region ($\bar{q}$), due to the increased flame temperature (T_f) and turbulence level under larger Re_a. Fuel-rich flames produce low fuel utilization efficiency and low heat flux and should be avoided in the practical applications. Fuel-lean condition in the range of $\Phi = 0.9$ to $\Phi = 1.1$ is found to be a desirable operation condition for its high heat flux and fuel efficiency. The current study provides valuable information on the heat transfer optimization of this innovative port-array IDF.

13/02173 Kinetics of coal oxy-combustion by means of different experimental techniques

Senneca, O. and Cortese, L. *Fuel*, 2012, 102, 751–759.

A large number of papers reported measures of coal char conversion rate under combustion and gasification conditions. Measures involved a variety of coal and char types, as well as different experimental techniques, ranging from TGA to wire mesh reactors and drop tube furnaces. For oxy-combustion with flue gas recirculation the impact of CO_2 on the rate of combustion of char combustion is still controversial. In the present paper the rate of carbon conversion in O_2/CO_2 mixtures typical of oxyfuel conditions has been investigated by conventional as well as innovative experimental techniques, respectively isothermal/non-isothermal thermogravimetric analysis and reaction in an aerodynamic levitator particle reactor (ALPR). Results show that the ALPR provides reliable results also at values of temperature and oxygen concentration where thermogravimetric analysis fails. Experimental results have been worked out to obtain simple rate expressions for oxy-fuel combustion. Commonly used kinetic laws, however, proved unable to fit the experimental results in the whole range of operating conditions.

13/02174 Numerical and experimental characterization of a batch bread baking oven

Ploteau, J. P. *et al. Applied Thermal Engineering*, 2012, 48, 289–295.

This study deals with the thermal characterization of an electrical static oven used for bread baking. The heating is provided by natural convection, infrared radiation and conduction with a cement slab. The paper describes a methodology to apprehend the heat flux which is applied to the products during baking. The oven was experimentally investigated and a finite element numerical model is established. The monitoring of temperatures at various points in the installation and of electrical power is carried out. Then, to characterize thermal exchanges around the bread during curing, thermal responses of a cylindrical sample is also measured. The numerical model made it possible to calculate the heat flux exchanges with the product, while separating the contributions of convection and radiation. The comparison of simulated responses with experimental data shows the relevance of the model.

13/02175 PAHs, carbonyls, VOCs and $PM_{2.5}$ emission factors for pre-harvest burning of Florida sugarcane

Hall, D. *et al. Atmospheric Environment*, 2012, 55, 164–172.

Emission factors (EFs) for hazardous polycyclic aromatic hydrocarbons (PAHs), carbonyls, and volatile organic compounds (VOCs) as well as other species such as $PM_{2.5}$, elemental carbon (EC), organic carbon (OC), and tracer compounds [e.g. levoglucosan (LG) and other sugars] were investigated for sugarcane pre-harvest burning in Florida. A combustion chamber was used to simulate field burning conditions for determining EFs of both dry leaf and whole stalk biomass burning. Samples were collected from the chamber's exhaust duct following EPA sampling methods. The total PAH EFs were 7.13 ± 0.94 and $8.18 \pm 3.26\,\mathrm{mg\,kg^{-1}}$ for dry leaf and whole sugarcane stalk burning, respectively. Carbonyl EFs were 201 ± 39 and $942 \pm 539\,\mathrm{mg\,kg^{-1}}$ for dry leaf and whole stalk burning, respectively. PAH and carbonyl emissions were dominated by lower molecular weight compounds (e.g. naphthalene and formaldehyde, respectively). Of the aromatic VOCs studied, benzene was the predominant species. The $PM_{2.5}$ EF was $2.49 \pm 0.66\,\mathrm{g\,kg^{-1}}$, which is in range of the current published AP-42 EFs for particulate matter emissions from sugarcane burning and other sugarcane studies. The OC, EC and LG EFs were 0.16 ± 0.09, 0.71 ± 0.22 and $7.87 \pm 5.42\,\mathrm{mg\,kg^{-1}}$, respectively. EFs of gaseous pollutants were generally lower than EFs from studies of agricultural residue combustion, likely due to the high combustion efficiency observed in this study.

13/02176 Pyrolysis of rubber tyre wastes: a kinetic study

Miranda, M. *et al. Fuel*, 2013, 103, 542–552.

The purpose of the present study was the analysis of possible routes for the pyrolysis reaction mechanism of rubber tyre wastes (RT). For this purpose, an evaluation was performed integrating both experimental data and different kinetic models. As none of the mechanisms found in literature allowed the numerical adjustment to the experimental data, new pathways were tested. Rubber tyre wastes kinetic studies were performed in order to evaluate possible direct conversions into new products (solids, liquids and gaseous), parallel reactions and/or reversible elementary steps. All experiments were carried out in a microautoclave system and based on the results obtained, at different temperatures and reactions times, kinetics models were evaluated and reactions pathways were established. Furthermore, products composition were analysed and according to the experimental data different reaction mechanisms were proposed. Afterwards, the kinetic data was compared with the experimental data. The proposed models were found to fit with the experimental data, which has allowed several explanations for the thermal degradation of rubber tyre waste to be proposed. Kinetics parameters were estimated, the dependence of activation energy and pre-exponential factor on temperature were evaluated. It was found that the rate constant of a number of reactions exhibited non-linear temperature dependence on the logarithmic form of Arrhenius law, which strongly suggest that reaction temperature has an effect on reaction mechanism of rubber tyre wastes pyrolysis.

13/02177 Rotary kiln pyrolysis of straw and fermentation residues in a 3 MW pilot plant – influence of pyrolysis temperature on pyrolysis product performance

Kern, S. *et al. Journal of Analytical and Applied Pyrolysis*, 2012, 97, 1–10.

The idea of co-firing biomass in an already existing coal-fired power plant could play a major contribution in the reduction of carbon dioxide emissions. Huge amounts of unused biomass in terms of agricultural residues such as straw, which is a cheap and local feedstock, are often available. But due to the high amount of corrosive ash elements (K, Cl, etc.), the residues are usually not suitable for co-firing in a thermal power plant. Therefore, the feedstock is converted by low temperature pyrolysis into gaseous pyrolysis products and charcoal. A 3 MW pyrolysis pilot plant located next to a coal-fired power plant near Vienna was set up in 2008. For the process, an externally heated rotary kiln reactor with a design fuel power of 3 MW is used which can handle about 0.6–0.8 t/h straw. The aim is to investigate the fundamentals for scale-up to the desired size for co-firing in a coal-fired power plant. In addition to the desired fuel for the process, which is wheat straw, a testing series for DDGS was also performed. The high amount of pyrolysis oil in the gas had positive effects on the heating value of the pyrolysis gas. Chemical efficiencies of this pyrolysis pilot plant of up to 67% for pyrolysis temperatures between 450 and 600 °C can be reached. The focus of this work is set on the pyrolysis products and their behaviour at different pyrolysis temperatures as well as the performance of the pyrolysis process.

13/02178 Slow and pressurized co-pyrolysis of coal and agricultural residues

Aboyade, A. O. *et al. Energy Conversion and Management*, 2013, 65, 198–207.

The distribution of products from the slow heating rate pyrolysis of coal, corn residues (cobs and stover), sugarcane bagasse and their blends were investigated by slow pressurized pyrolysis in a packed bed reactor. A factorial experimental design was implemented to establish the relative significance of coal–biomass mix ratio, temperature and pressure on product distribution. Results showed that the yield and composition of tar and other volatile products were mostly influenced by mix ratio, while temperature and pressure had a low to negligible significance under the range of conditions investigated. Analysis of the composition of condensates and gas products obtained showed that there was significant synergy or chemical interactions in the vapour phase during co-pyrolysis of coal and biomass. However, the interactions did not significantly affect the relative distribution of the lumped solid, liquid and gas products obtained from the blends, beyond what would be expected assuming additive behaviour from the contributing fuels.

13/02179 The effect of variable fuel composition on a swirl-stabilised producer gas combustor

Lewis, J. *et al. Energy Conversion and Management*, 2012, 64, 52–61.

Producer gas is a form of synthesis gas formed from the gasification of biomass. Its composition varies largely depending on the gasifier type, up-draft, down-draft and entrained flow to name a few, and oxidizer, typically air, steam or pure oxygen. The producer gas in question is derived from an air fed down-draft gasifier containing grade A wood waste, and as such has comparatively low calorific value and hydrogen content of around $6\,\mathrm{MJ/N\,m^3}$ and 11% respectively. The viability of producing thermal energy on an industrial scale was proved via the swirl-stabilized combustion of forementioned producer gas in a 1.5 MW rated swirl burner, directly attached to a proprietary gasification plant. A largely stable combustion was achieved; however, a few instances of flame extinction did occur which were attributed to varying fluctuations in gasifier throat temperature. A relationship between throat temperature and fuel composition is believed to be the cause of these extinctions. Although these fluctuations were shown to have little effect on the producer gases stoichiometric air-to-fuel ratio and calorific value, there was particular variance in hydrogen content. Simulation using CHEMKIN showed that this variable hydrogen content had a significant effect on flame speed, with an increase from 5% to 15% hydrogen increasing laminar flame speed from 8.01 to 17.70 cm/s. Industrial-scale data was also compared to that taken with a 100 kW laboratory-scale combustor in an attempt to establish whether burner optimization could be effectively achieved in a controlled laboratory environment. A relationship was found between exhaust temperature and introduction of axial air, which extended across both burners. Flame speed and flame temperature simulations also showed that air is an acceptable diluent of natural gas when substituting for producer gas.

13/02180 The reduction of soot formation from fuels using oxygenates additives

Burshaid, K. I. and Hamdan, M. A. *Energy Conversion and Management*, 2013, 65, 751–754.

This work presents an experimental technique for the measurement of the soot formation in pure fuel, biofuel and emulsified fuel, that constitute this fuels was studied in heated shock tube and investigated the possibility of reducing soot production in locally refined diesel, locally produced biofuel and emulsified fuel. This reduction was conducted using certain oxygenated additives (methane, ethane and acetone). It was found that soot concentration is maximum when pure diesel was burned, followed by emulsified fuels and the lease concentration was obtained when biofuel was burned. Further, methanol has the most significant effect on the reduction of soot once added to each fuel, while acetone has the lease effect on soot reduction. The results gave good indication of the effect for oxygenated additives in reduction the soot formation.

13/02181 The synthesis and catalytic performances of three-dimensionally ordered macroporous perovskite-type $LaMn_{1-x}Fe_xO_3$ complex oxide catalysts with different pore diameters for diesel soot combustion

Zheng, J. *et al. Catalysis Today*, 2012, 191, (1), 146–153.

Polymethyl methacrylate (PMMA) microspheres with diameters of 300–800 nm were synthesized by a modified emulsifier-free emulsion polymerization technique with water–oil biphase double initiators. The obtained PMMA microspheres did not aggregate and their size distribution was narrow. Three-dimensionally ordered macroporous (3DOM) $LaMn_{1-x}Fe_xO_3$ ($x = 0$, 0.05, 0.1, 0.15) with different pore diameters were prepared by the means of colloidal crystal template method using PMMA microspheres with different diameters as templates. The microspheres and 3DOM catalysts were characterized by means of powder X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier transformation infrared spectroscopy (FT-IR), nitrogen adsorption–desorption and laser particle size analysis. All the catalysts possessed 3DOM structure with hexagonal well-ordered array. Their macroporous diameters were in the range of 140–600 nm. The catalytic performances of the catalysts for diesel soot combustion were investigated by temperature-programmed oxidation (TPO) reaction. The 3DOM $LaMn_{1-x}Fe_xO_3$ catalysts had good catalytic performances for diesel soot combustion, and their catalytic activities increased with the increasing of pore diameters.

13/02182 Wood consumption and analysis of the bread baking process in wood-fired bakery ovens

Manhiça, F. A. *et al. Applied Thermal Engineering*, 2012, 47, 63–72.
Combustion of biomass in small-scale furnaces is used widely in different applications. The technology used is often ‘fixed grate’ combustion in small batch furnaces. The efficiency of such a furnace is often low, which results in a high environmental impact. The aim of this work was to analyse the performance of the existing wood-fired bakery ovens that can be used to improve the efficiency. The data collected from 15 semi-direct and three indirect bakeries consisted of: the dimensions of the oven, the temperature profiles of the combustion chamber and the baking oven, the baking time and the bread quality. It was found that as much as 60 tons/day of green wood are consumed in the bread baking process in the area investigated. Two types of bakery ovens are used most commonly: indirect and semi-direct. The specific consumption was found to be 0.55 and 0.90 kg of wood per kg of wheat flour baked for the indirect and the semi-direct respectively. The analyses of the bread baked show that the variation of the temperature profile during the baking process influences the quality of the bread produced.

Fire safety

13/02183 A comprehensive risk assessment framework for offsite transportation of inflammable hazardous waste

Das, A. *et al. Journal of Hazardous Materials*, 2012, 227–228, 88–96.
A framework for risk assessment due to offsite transportation of hazardous wastes is designed based on the type of event that can be triggered from an accident of a hazardous waste carrier. The objective of this study is to design a framework for computing the risk to population associated with offsite transportation of inflammable and volatile wastes. The framework is based on traditional definition of risk and is designed for conditions where accident databases are not available. The probability based variable in risk assessment framework is substituted by a composite accident index proposed in this study. The framework computes the impacts due to a volatile cloud explosion based on TNO multi-energy model. The methodology also estimates the vulnerable population in terms of disability-adjusted life years which takes into consideration the demographic profile of the population and the degree of injury on mortality and morbidity sustained. The methodology is illustrated using a case study of a pharmaceutical industry in the Kolkata metropolitan area.

13/02184 Effect of distance, meteorology, and burn attributes on ground-level particulate matter emissions from prescribed fires

Pearce, J. L. *et al. Atmospheric Environment*, 2012, 56, 203–211.
Multiple air monitoring campaigns were conducted from 2003 to 2007 during the months of December through April in which time-integrated monitoring of $PM_{2.5}$ was performed during 55 prescribed burn (PB) events administered under select meteorological conditions. The data were analysed using a generalized additive mixed-model (GAMM) where the logarithm of $PM_{2.5}$ concentrations were modelled as the sum of linear and non-linear functions of the covariates of interest after accounting for the confounding associated with the grouping structure of the data and spatial dependency. This model explained 61% of the variance of log transformed $PM_{2.5}$. The GAMM component of the model (i.e. the covariates of interest) explained 40% of that variance and the mixed-model component (i.e. random-effects and spatial correlation) explained 21%. Within burn events, concentrations across the air monitoring grid were significantly influenced by the distance from burn perimeter to air monitor and the proportion of time the air monitor was in line with the wind field over the burn. Among burns, variation was significantly influenced by burn duration, burn size, mode of ignition, and regional background $PM_{2.5}$; indicating the importance of these for fire management. Measures of burn intensity and meteorology were found to be insignificant in this model; however, it is possible that some of these effects were absorbed by the random-effects of the model. These findings demonstrate that downwind exposure is largely a function of wind direction combined with distance from the burn and that emissions from one burn to the next are dependent on burn size, duration, and mode of ignition.

13/02185 Experimental observations of complex flame propagations initiated at different locations of an impingement configuration

McDaid, C. *et al. Fuel*, 2013, 103, 783–791.
The effect of ignition location on the propagation of premixed and diffusion flames of hydrogen and mixtures of hydrogen and carbon dioxide towards and away from an impingement plate was studied using distance-time relations and velocity–time curves for the edge of the flame boundary at the centre line. It is shown that ignition location, fuel composition and jet velocity have large effects on the flame propagation speed, and non-linear acceleration was observed for flames ignited at the plate. The effect of the angle of mixing of the unburned fuel with the surrounding air was found to have an effect on the downwards propagation, and also, delay of downwards propagation after ignition was observed for some cases. It was found that air/fuel premixing hinders the initial downwards propagation of the flame when ignited at the plate. Propagation velocities of up to $25\,m\,s^{-1}$ were observed when the flame was ignited at the nozzle, aided by the velocity of the fuel jet. However, accelerations much higher than the gravitational acceleration were observed, indicating that buoyancy may not be a significant factor in the high velocities of the flames. It was also found that jet velocity had a higher effect on the propagation velocity for the premixed and H_2/CO_2 flames than the diffusion flames.

13/02186 Full-scale experiments of fire suppression in high-hazard storages: a temperature-based analysis of water-mist systems

Santangelo, P. E. and Tartarini, P. *Applied Thermal Engineering*, 2012, 45–46, 99–107.
Water-mist systems have become quite popular over the last two decades as an innovative technology in fire protection. Moreover, insertion of additives to the flow may be applied to provide additional improvements in terms of suppression effectiveness and temperature control. The present work consists of an experimental approach within a real-scale facility, which has been aimed at challenging water mist against severe fire scenarios. Among them, a high-rise storage has been here explored, being it commonly recognized as strongly hazardous even by technical standards in terms of both nominal fire load and designed physical domain. The system configuration presents high-pressure nozzles at the ceiling; the sole-water flow is compared to water endowed with a commercial additive. The thermal transient within the test chamber has been evaluated during the fire development as the main quantitative parameter; moreover, the fire evolution has been visualized through a post-fire estimation of the damages. Despite the large amount of released smoke and smouldering materials, water mist is shown to be efficient in fire control, if endowed with the chosen additive. On the other hand, the sole-water flow does not appear suitable for such hazardous conditions under the designed nozzle arrangement.

13/02187 Interactions of fire emissions and urban pollution over California: ozone formation and air quality simulations

Singh, H. B. *et al. Atmospheric Environment*, 2012, 56, 45–51.
An instrumented DC-8 aircraft was employed to perform airborne observations in rural and urban environs of California during the summer 2008 NASA ARCTAS-CARB campaign. The fortuitous occurrence of large wildfire episodes in Northern California allowed for studies of fire emissions, their composition, and their interactions with rural and urban air. Relative to CO, emissions of HCN were shown to vary non-linearly with fire characteristics while those of CH_3CN were nearly unchanged, making the latter a superior quantitative tracer of biomass combustion. Although some fire plumes over California contained little NO_x and virtually no O_3 enhancement, others contained ample VOCs and sufficient NO_x, largely from urban influences, to result in significant ozone formation. The highest observed O_3 mixing ratios (170 ppb) were also in fire-influenced urban air masses. Attempts to simulate these interactions using CMAQ, a high-resolution state of the art air quality model, were only minimally successful and indicated several shortcomings in simulating fire emission influences on urban smog formation. A variety of secondary oxidation products (e.g. O_3, PAN, HCHO) were substantially under-estimated in fire-influenced air masses. Available data involving fire plumes and anthropogenic pollution interactions are presently quite sparse and additional observational and mechanistic studies are needed.

13/02188 Thermal properties and combustion behaviors of flame retarded epoxy acrylate with a chitosan based flame retardant containing phosphorus and acrylate structure

Hu, S. *et al. Journal of Analytical and Applied Pyrolysis*, 2012, 97, 109–115.

Functional materials prepared from natural resources arouse a great interest recently. Herein, a novel natural material based flame retardant chitosan phosphate acrylate (GPCS) containing phosphorus and acrylate structure has been prepared. Its effect on thermal properties and combustion behaviours of epoxy acrylate (EA) has been investigated. Microscale combustion calorimeter (MCC) data showed that GPCS reduced the peak heat release (PHRR) and total heat release (THR) of samples greatly, which meant that GPCS was efficient in reducing the flammability of EA. The results of thermogravimetric analysis (TGA) exhibited that GPCS improved the thermal stability of materials at high temperature. Investigation of real-time Fourier transform infrared (RT-IR) and thermogravimetric analysis/infrared spectrometry (TGA-IR) revealed that GPCS promoted the formation of char and reduced the release of combustible gas. Thermomechanical properties data showed that the storage modulus of samples increased then decreased with increasing GPCS content while the glass transition temperature continued reduced.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

13/02189 An inverse method to estimate the moving heat source in machining process

Luchesi, V. M. and Coelho, R. T. *Applied Thermal Engineering*, 2012, 45–46, 64–78.

The present work propounds an inverse method to estimate the heat sources in the transient two-dimensional heat conduction problem in a rectangular domain with convective bounders. The non-homogeneous partial differential equation is solved using the integral transform method. The test function for the heat generation term is obtained by the chip geometry and thermomechanical cutting. Then the heat generation term is estimated by the conjugated gradient method with adjoint problem for parameter estimation. The experimental trials were organized to perform six different conditions to provide heat sources of different intensities. This method was compared with others in the literature and advantages are discussed.

13/02190 Assessment of energy and exergy efficiencies of a grate clinker cooling system through the optimization of its operational parameters

Ahamed, J. U. *et al. Energy*, 2012, 46, (1), 664–674.

Grate coolers are widely used in cement industries to recover heat from hot clinker, coming out from the rotary kiln. This study focuses on improving the energy, exergy and recovery efficiencies of a grate cooling system through the optimization of its operational parameters such as masses of cooling air and clinker, cooling air temperature, and grate speed. It has been found that the energy and recovery energy efficiencies of a cooling system can be increased by 1.1% and 1.9%, respectively, with every 5% mass increases of cooling air. Similarly, it has been estimated that energy and recovery energy efficiencies can be increased by 2.0% and 0.4% with every 5% increase of cooling temperature. The exergy and its recovery efficiencies found to be increased by 3.6% and 2.2%, respectively, for the same condition. Energy efficiency and energy recovery efficiencies are increased by 3.5% and 1.4% with every 9.1% increase of grate speed. Using heat recovery from the exhaust air, energy and exergy recovery efficiencies of the cooling system found to be increased by 21.5% and 9.4%, respectively. It has been found that about 38.10% and 30.86% energy cost can be saved by changing mass flow rate of clinker and mass flow rate of cooling air, respectively.

13/02191 Biomass co-firing trials on a down-fired utility boiler

Steer, J. *et al. Energy Conversion and Management*, 2013, 66, 285–294.

This paper describes the practical combustion issues encountered with biomass co-firing on a large scale trial in a 500 MW down fired utility boiler at Aberthaw power station. It also investigates and discusses the effect of biomass particle size and physical properties on devolatilization; flame stability; and slagging by using the biomass energy crop miscanthus. During large-scale biomass co-firing, the air flow around the injectors plays an important part in the fuel combustion and stable boiler operation. Secondary air flow at the point of biomass injection was adjusted during the experiments to provide higher airflows around the biomass injectors, hence the mixing, and air available for biomass combustion, was improved producing less unburned material in the ash and reducing potential filter blockages. However, higher biomass air flows disrupt the temperature distribution in the boiler causing a wider variation of superheater temperatures compared to the baseline condition firing coal only. This reduces the combustion efficiency and can lead to localized hot spots, in the superheaters, with the potential to cause equipment damage. The trials indicated during the experiments that a secondary biomass air flow of 50% of its maximum, gave an optimum balance between air/biomass mixing and variations in the superheater temperatures.

13/02192 CFD analysis of pressure loss during flow by hydraulic directional control valve constructed from logic valves

Lisowski, E. and Rajda, J. *Energy Conversion and Management*, 2013, 65, 285–291.

The aim of this paper is to investigate the reduction of flow resistance in a hydraulic system. The undertaken matter is focused on a spool-type directional control valve with pilot operated check valves. In the paper there is a proposition of replacing a four-way directional control valve with pilot operated check valves by suitable unit consisting of logic valves. Therefore, a body of new directional control valve has been designed. Four logic valves are mounted on the body and closed with a cover on which electromagnetic pilot valve is assembled. The hydraulic ports of the body are in accordance with the standard ISO 4401–08–07–0–94, so the proposed new directional control valve can be applied alternatively to a directional spool valve. An important task given during the work is to create the systems of flow paths inside the body, which are assumed to be performed with simple technologies like: drilling, boring and milling. The system of the designed flow paths is verified by computational fluid dynamics (CFD) analysis with the use of ANSYS/Fluent program on three-dimensional model. Obtained results are compared with the results of the characteristics given in catalogues and coming from experimental research of the prototype. The difference in pressure loss during flow for the logic valve taken from CFD calculation and the catalogue do not exceed 5%. Presented in the paper directional control valve may operate for volumetric flow rate up to 450 dm^3/min and the pressure up to 42 MPa. In the proposed solution, although simple technologies of making flow paths were applied, the pressure losses were reduced over 35%. The developed solution is close to a standard directional spool valve and can be assembled on an identical sub-plate.

13/02193 Combined alkaline and ultrasound pre-treatment of thickened pulp mill waste activated sludge for improved anaerobic digestion

Park, N. D. *et al. Biomass and Bioenergy*, 2012, 46, 750–756.

Samples of pulp mill waste activated sludge were thickened by centrifugation, from approximately 25 to approximately 65 g kg^{-1} TS, and subjected to combined alkaline (NaOH dosage of 0.206 and 0.261 g g^{-1} TS, respectively) and ultrasonic (39.6 and 16.8 MJ kg^{-1} TS, respectively) pre-treatment. Pre-treatment increased the soluble TS, VS and COD of the pulp sludge 3–14 times over non-treated sludge. Batch anaerobic digestions were used to compare the effects of sludge pre-treatment. Pre-treatment did not significantly improve biogas production over 28 d, but did increase VS reduction (21 ± 3 to $30 \pm 0.8\%$ for the 25 g kg^{-1} TS sludge and 23 ± 0.5 to $27 \pm 0.7\%$ for 65 g kg^{-1} TS sludge). Pre-treatment increased the initial rate of methane production. Eighty per cent of the total methane production was reached 5–6 d earlier when pre-treated. Overall methane production was found to be 404 ± 205 and 222 ± 123 mL g^{-1} VS$_{\text{consumed}}$ for 25 g kg^{-1} TS sludge non-treated and pre-treated sludge and 384 ± 183 and 354 ± 93 mL g^{-1} VS$_{\text{consumed}}$ for 65 g kg^{-1} TS non-treated and pre-treated sludge. Pre-treatment reduced the dewaterability of both sludges. Thickening by centrifugation reduced the total S content of the dried sludge. Overall, biogas production from pulp sludge was unstable and inconsistent. Further research is required to determine the cause of inhibition.

13/02194 Combining physical and economic output data to analyse energy and CO_2 emissions trends in industry

Cahill, C. J. and Gallachóir, B. P. Ö. *Energy Policy*, 2012, 49, 422–429.

Index decomposition analysis based on economic output is frequently employed to provide an indication of energy intensity trends in industry. Additionally, composite energy efficiency indicators, calculated using physical output, are used to give a more accurate view of energy efficiency progress. Both approaches are commonly presented in one study but often with a different mathematical basis for each. This may lead to inconsistent results. This study demonstrates using practical case studies that, when all physical and economic output data are available for industry sub-sectors, can be combined in a single decomposition analysis that provides an energy efficiency indicator based on physical production and an indicator of the influence of structural change based on value added. Using the same methodology for both results ensures that the results are consistent and provides insights into the effects of changing prices of goods on aggregate energy intensity. In the case studies examined, falling unit values of industrial goods produced over time tend to increase the energy intensity of industry.

13/02195 Desalination using low grade heat in the process industry: challenges and perspectives

Ammar, Y. *et al. Applied Thermal Engineering*, 2012, 48, 446–457.

This paper examines the use of low grade heat from process industries for thermal desalination processes as this is relevant not only to current energy conservation schemes but also may play a role in increasing the capacity to satisfy future water demands. The study focuses on low grade heat sources from a paper mill located on a British coastal area which presents a large quantity of recoverable waste heat at low temperature (<100 °C). Two scenarios are considered: (i) low grade heat is used directly to feed the desalination process, (ii) low grade heat is upgraded using a heat pump coupled with a desalination system. In the first scenario, a Humidification Dehumidification process was identified as a suitable technology due to its low operating temperature. In the second scenario, the low grade heat temperature was upgraded using a hybrid absorption heat pump and subsequently used to feed a multiple effect distillation desalination system. These two cases were compared in terms of performances and economics. For both cases, a payback period of less than 10 years could be obtained for water price equal to £2 per tonne of water. This is comparable to the price of home water supply. Environmental aspects were also discussed from the results of a full lifecycle assessment. Low grade heat utilization in both cases reduced the global warming potential in comparison with fossil fuel powered systems, but toxicological impacts appeared higher in comparison to a system using natural gas.

13/02196 Designing a methodology for integrating industry practice into a probabilistic overheating tool for future building performance

Jenkins, D. P. *et al. Energy and Buildings*, 2012, 54, 73–80.

The Low Carbon Futures project, funded by the Adaptation and Resilience in a Changing Climate Programme, has the objective of using the latest UK climate projections to assess overheating in a range of domestic and non-domestic buildings. As these climate projections are probabilistic in nature, and dynamic building simulation is being used by the project to assess building performance, the information produced is vast. To understand how to filter this data into a useable tool that can interact with current building practices, the project has commissioned a range of focus groups to obtain practitioner feedback. These focus groups provide guidance on how buildings are currently designed with respect to overheating but also how future overheating risk assessments, incorporating probabilistic climate projections, might be carried out. This paper describes the assimilation of all this research into a coherent building simulation methodology that could be used by building practitioners to assess future overheating risks of a range of buildings, and provide guidance for applying adaptation solutions to prevent defined comfort thresholds being exceeded.

13/02197 Embodied energy use in China's industrial sectors

Liu, Z. *et al. Energy Policy*, 2012, 49, 751–758.

As the world's top energy consumer, China is facing a great challenge to solve its energy supply issue. In this paper energy use from all industrial sectors in China's economy of 2007 was explored by conducting an extended environmental input–output analysis. The authors compare the energy consumption embodied in the final demand for goods and services from 29 sectors with the energy demand required for the actual production process in each sector. Two different viewpoints for sectoral energy use have been presented: energy use is directly allocated to the producer entity, and energy use is reallocated to sector's supply chain from consumption perspective. The results show that considerable amount of energy use is embodied in the supply chain, especially for 'construction' and 'other service activities' sectors, which is not detected if energy use is allocated on a production basis. When further dividing embodied energy consumption into direct energy consumption and indirect energy consumption, total indirect energy consumption is much higher than that of total direct energy consumption, accounting for 80.6% of total embodied energy consumption in 2007. The results provide a more holistic picture on sectoral energy consumption and therefore can help decision-makers make more appropriate policies.

13/02198 Energy and exergy utilizations of the Jordanian SMEs industries

Al-Ghandoor, A. *et al. Energy Conversion and Management*, 2013, 65, 682–687.

This study presents detailed analysis of the energy and exergy utilizations of the Jordanian small to medium enterprises (SMEs) by considering the flows of energy and exergy through the main end uses in the Jordanian industrial sector. To achieve this purpose, a survey covering 180 facilities was conducted and energy consumption data was gathered to establish detailed end-use balance for the Jordanian industrial sector. The energy end-use balance provides a starting point to estimate the site and embodied energy and exergy efficiencies. The average site energy and exergy efficiencies of the Jordanian SMEs industries sector are estimated as 78.3% and 37.9%, respectively, while the embodied energy and exergy efficiencies are estimated as 58.9% and 21.2%, respectively. The low efficiencies values suggest that many opportunities for better industrial energy utilizations still exist.

13/02199 Energy conversion strategies in the European paper industry – a case study in three countries

Laurijssen, J. *et al. Applied Energy*, 2012, 98, 102–113.

The pulp and paper industry both uses and produces large amounts of energy and rising fuel prices bring along significant challenges to the sector. Several strategies can be applied in order to remain competitive, e.g. an increase in energy efficiency, a switch in fuel and/or a novel energy conversion technology. This study, investigates whether improved energy conversion strategies can reduce energy costs, primary energy use and CO_2 emissions of paper mills within different European countries (The Netherlands, Poland and Sweden). The results show that differences in history and availability of resources has led to different conversion strategies in the three countries. The authors found that a natural gas combined cycle, which is largely implemented in The Netherlands due to long term domestic availability of natural gas, has the lowest primary energy demand. Due to a long history of low electricity prices, CHP has not been common in Sweden. Many Swedish mills use biomass as an energy source and due to low CO_2 emissions of the national grid the CO_2 emission profile of the Swedish paper industry is very low. The results imply that future conversion routes for the Swedish paper and board industry are again wood based; in case of increasing electricity prices these would be biomass gasification based CHP solutions. With a reduction of 800 kg CO_2/ton paper on average, a switch from coal to biomass would reduce CO_2 emissions in the Polish pulp and paper industry with approximately 0.6 Mton/year. A carbon price of €20–25/ton would, according to The results, be enough to provoke this switch. Due to the high share of natural gas, the CO_2 emission reduction potential of the Dutch paper industry (1.5 Mton/year) is even larger than in Poland. Due to high biomass prices and relative low CO_2 emission profile of natural gas, a carbon prices of more than €60/ton CO_2 would be needed to provoke a switch in The Netherlands. Provided with few alternatives, the most effective strategy in The Netherlands would be an increase in energy efficiency.

13/02200 Energy saving in sugar manufacturing through the integration of environmental friendly new membrane processes for thin juice pre-concentration

Gul, S. and Harasek, M. *Applied Thermal Engineering*, 2012, 43, 128–133.

In the present work energy savings in clarified thin sugar juice preheating and concentration are presented by integrating a new pressure-driven multistage membrane process with multiple-effect evaporator (MEE). The thin sugar juice is concentrated from 15 to 50 wt% with membrane and from 50 to 70 wt% in MEE. The new process will not only reduce the energy consumption of thin juice concentration process significantly but will also reduce the requirements of energy and heat transfer area of heat exchangers for pre-heating the thin juice before evaporation by 70%. The existing sugar factories may increase the capacity of their evaporation station through the integration of the new membrane process while new factories to be built will have a smaller sized evaporation station with more energy efficiency and environmentally friendly process performance and with a significantly smaller carbon footprint.

13/02201 Experiment and grey relational analysis of seaweed particle combustion in a fluidized bed

Wang, S. *et al. Energy Conversion and Management*, 2013, 66, 115–120.

Seaweed particles were introduced to a bench-scale fluidized bed furnace to study the combustion of seaweed biomass (*Enteromorpha clathrata*). Quartz sand was used as the bed material. After dehydration and devolatilization, the *E. clathrata* char particle then burned according to the shrinking core conversion pattern. In order to identify key operating variables affecting seaweed combustion in fluidized bed. These operating variables (bed temperature, fluidization velocity and bed material height) were chosen as influential factors in this experiment. The mass ratio of the residual fixed carbon to parent fixed carbon was calculated to evaluate the influential factors. The grey relational analysis was used to study the degree of relative importance of the influential factors. Calculation results indicated that the influence of the bed height is the least, the bed temperature had the greatest influence. The experimental results and grey relational analysis can provide reference data for design of seaweed circulating fluidized bed furnaces.

13/02202 Experimental study on the effect of N_2, CO_2, and steam dilution on the combustion performance of H_2 and CO synthetic gas in an industrial gas turbine

Lee, M. C. *et al. Fuel*, 2012, 102, 431–438.

This study investigates the combustion performance of synthetic gas that is composed of hydrogen, carbon monoxide, nitrogen, carbon dioxide and steam, and evaluates the dilution effect of the last three gases. Combustion tests of a model GE7EA industrial gas turbine are conducted at ambient pressure and the air inlet temperature of 380 °C. NO_x and CO emissions, combustion instabilities, flame shapes, and the temperature at several points of the combustion chamber are observed while varying the dilution ratio of nitrogen, carbon dioxide and steam. NO_x emissions are decreased as the amount of diluents is increased, and the reduction of NO_x emission per unit power generation is logarithmically related only to the diluent's heat capacity which is the product of mass flow rate of diluent and constant pressure heat capacity. In most of the tested cases, the combustion efficiency is satisfactorily good in that CO is emitted below 10 ppm, and neither flash back nor combustion instability is observed. From the results, it was reported that nitrogen, carbon dioxide and/or steam are applicable to a syngas turbine to control NO_x emission with ensuring reliable operation.

13/02203 Industrial energy efficiency with CO_2 emissions in China: a nonparametric analysis

Wu, F. *et al. Energy Policy*, 2012, 49, 164–172.

Global awareness on energy security and climate change has created much interest in assessing economy-wide energy efficiency performance. A number of previous studies have contributed to evaluate energy efficiency performance using different analytical techniques among which data envelopment analysis (DEA) has recently received increasing attention. Most of DEA-related energy efficiency studies do not consider undesirable outputs such as CO_2 emissions in their modelling framework, which may lead to biased energy efficiency values. Within a joint production framework of desirable and undesirable outputs, this study constructs both static and dynamic energy efficiency performance indexes for measuring industrial energy efficiency performance by using several environmental DEA models with CO_2 emissions. The dynamic energy efficiency performance indexes have further been decomposed into two contributing components. Finally, the indexes are applied to assess the industrial energy efficiency performance of different provinces in China over time. This empirical study shows that the energy efficiency improvement in China's industrial sector was mainly driven by technological improvement.

13/02204 Integrated IDA–ANN–DEA for assessment and optimization of energy consumption in industrial sectors

Olanrewaju, O. A. *et al. Energy*, 2012, 46, (1), 629–635.

This paper puts forward an integrated approach, based on logarithmic mean divisia index (LMDI) – an index decomposition analysis (IDA) method, an artificial neural network (ANN) and a data envelopment analysis (DEA) for the analysis of total energy efficiency and optimization in an industrial sector. The energy efficiency assessment and the optimization of the proposed model use LMDI to decompose energy consumption into activity, structural and intensity indicators, which serve as inputs to the ANN. The ANN model is verified and validated by performing a linear regression comparison between the specifically measured energy consumption and the corresponding predicted energy consumption. The proposed approach utilizes the measure-specific, super-efficient DEA model for sensitivity analysis to determine the critical measured energy consumption and its optimization reductions. The proposed method is validated by its application to determine the efficiency computation and an analysis of historical data as well as the prediction and optimization capability of the Canadian industrial sector.

13/02205 Measures and potentials of energy-saving in a Chinese fine chemical industrial park

Tian, J. *et al. Energy*, 2012, 46, (1), 459–470.

This study aims to fill the gap in the literature on energy efficiency and economic analysis of energy-saving measures at the industrial park level by conducting a case study of a typical fine chemical industrial park in China. Based on a 5-year intensive data collection, the authors quantitatively examined the energy consumption and energy efficiency of the industrial park in question and evaluated the energy-saving potentials and cost-effectiveness of 10 types of energy-saving measures by means of a bottom-up method and scenario analysis. It was found that the energy efficiencies of its two combined heat and power plants in 2007 were 81.5% and 56%, respectively. Energy efficiency of the fine chemical industrial park was around 4625.7 GJ per US$ million of gross industrial output value, which was only between 20% and 25% of that of the sector of manufacturing raw chemical materials and chemical products in China. The energy-saving potentials of the 10 measures amount to about 11% of energy consumption of the industrial park in 2007. A total capital investment of approximately US$35 million would be needed to realize the potentials. The technical measures explored in the study are generally replicable in other Chinese fine chemical industrial parks.

13/02206 Modeling a vanadium redox flow battery system for large scale applications

Turker, B. *et al. Energy Conversion and Management*, 2013, 66, 26–32.

A simulation model of a vanadium redox flow battery (VRFB) system based on measurements with a kilowatt scale real life VRFB unit was developed. Various hourly charging and discharging cycles were performed for states of charge (SOC) of 75%, 60%, 40% and 20% at different power values ranging from 2 to 10 kW. The dependence of the overall system efficiency in a VRFB unit on the SOC was determined by considering the energy losses at stacks during the electrochemical conversion and by the auxiliary power consumption of the hydraulic circuits as well as the power conversion systems. Using the model, optimal number of modules for certain power levels during charging and discharging operations were estimated for megawatt scale operations.

13/02207 Optimal control strategy for minimization of exergy destruction in boiler superheater

Ray, T. K. *et al. Energy Conversion and Management*, 2013, 66, 234–245.

Steam temperatures in large capacity boilers of modern electric power stations are maintained closely around the design specification by spraying water in the superheater (SH) attemperator to ensure safe and efficient operation and long plant life. Although the process of attemperation involves exergy destruction, and optimal controllers have previously been proposed for steam temperature control, prior studies on such controllers have not considered exergy as an important parameter. Exergy analysis of a two-stage SH attemperator with real time operation parameters in a 500 MWe pulverized fuel-fired power plant pinpoints the avenues for optimization that is beyond the scope of the traditional first law-based analysis. Strategies to minimize exergy destruction by suitably varying the proportions of stage I and stage II spray flows are established. Further, a MATLAB-SIMULINK-based model is developed and optimal control strategies are devised for SH steam temperature control following a linear quadratic regulator (LQR) approach. Variation of the process parameters and the exergy destructions during the transient operations of the attemperator under stipulated disturbances have been analysed using the model, with different values of the controller parameters. Guidelines are formulated for the spray flow controller tuning so that the total exergy destructions during the system transients are minimized.

13/02208 Quantitative feasibility study of magnetocaloric energy conversion utilizing industrial waste heat

Vuarnoz, D. *et al. Applied Energy*, 2012, 100, 229–237.

The main objective of this theoretical study was to investigate under which conditions a magnetic energy conversion device (MECD) – utilizing industrial waste heat – is economically feasible. Furthermore, it was evaluated if magnetic energy conversion (MCE) has the potential of being a serious concurrent to already existing conventional energy conversion technologies. Until now the availability of magnetocaloric materials with a high Curie temperature and a high magnetocaloric effect is rather limited. Therefore, this study was mainly focused on applications with heat sources of low to medium temperature levels. Magnetic energy conversion machines, containing permanent magnets, are numerically investigated for operation conditions with different temperature levels, defined by industrial waste heat sources and environmental heat sinks, different magnetic field intensities and different frequencies of operation (number of thermodynamic cycles per unit of time). Theoretical modelling and numerical simulations were performed in order to determine thermodynamic efficiencies and the exergy efficiencies as function of different operation conditions. From extracted data of the numerical results, approximate values of the total mass and total volume of magnetic energy conversion machines could be determined. These important results are presented dependent on the produced electric power. An economic feasibility study supplements the scientific study. It shows an excellent potential of profitability for certain machines. The most important result of this article is that the magnetic energy conversion technology can be economically and technically competitive to or even beat conventional energy conversion technologies. This is true especially in those cases when large, low-exergy heat sources are at one's disposal.

13/02209 RBF–ARX model of an industrial furnace for drying olive pomace

Casanova-Peláez, P. J. *et al. Energy Conversion and Management*, 2012, 64, 106–112.

Drying operations are common in food industries. One of the main components in a drying system is the furnace. The furnace operation involves heat–mass transfer and combustion, thus it demands a complex mathematic representation. Since autoregressive methods are simple, and help to simulate rapidly a system, a drying furnace of olive pomace was modelled via an auto-regression with exogenous variables (ARXs) method. A neural network of radial basic functions (RBFs) defines the ARX experimental relation between the amounts of dry pomace (moisture content of 15%) used like fuel and the temperature of outlet gases. A real industrial furnace is studied to validate the proposed model, which can help to control the drying process.

13/02210 System analysis of grain straw for centralised industrial usages in China

Li, Q. *et al. Biomass and Bioenergy*, 2012, 47, 277–288.

This paper provides analysis of the availability of grain straw resources for centralized industrial usages and suitable areas in China at the prefectural level. China has abundant straw resources for both decentralized and centralized usages. Decentralized usages are inefficient and cannot absorb enough straw. However, centralized usages have technological and economic problems, such as product cost and resource supply, and therefore, a system analysis of the economic available resources and suitable areas are needed. Three main grain crops – rice, wheat, and corn – and three typical centralized usages – paper making, direct combustion power generation, and bioethanol – are investigated in this study. An optimal model is established on the basis of straw resource characteristics and techno-economic characteristics of the usages and used to calculate the distribution of suitable prefectures and the largest supply of resources for each usage. The study focuses on prefectures in 13 provinces with relatively abundant grain straw resources. The suitable areas for paper making are in north China, for direct combustion power generation are in north and north-east China, for bioethanol are in north-east China. The largest economic available resources for paper making, direct combustion power generation, and bioethanol are 47.5, 221.4 and 164.4 million tons, respectively. The operation cost and the ratio of straw actually collected from production are selected for conducting a sensitivity analysis. The impacts of other factors, including the geographical environment, local product demand, existing industry, change in total straw production, technical progress and straw from other crops, are discussed.

10 SPACE HEATING AND COOLING/HEAT PUMPS

13/02211 Air-to-air heat pumps in real-life use: are potential savings achieved or are they transformed into increased comfort?

Gram-Hanssen, K. *et al. Energy and Buildings*, 2012, 53, 64–73.

This paper deals with individual air-to-air heat pumps in Danish dwellings and summerhouses and the question of to what extent they actually deliver savings of energy consumption. Results show that 20% of the expected reduction of electricity consumption is converted into increased comfort in the homes, including extended heating areas, keeping a higher temperature and a longer heating season and using the heat pump for air conditioning. Data include electricity consumption in 185 households before and after installation of heat pumps together with survey results of 480 households. Furthermore, 12 households were selected for in-depth analysis including technical inspection and qualitative interviewing. Especially for summerhouses, results indicate that on average there is no reduction in electricity consumption, as energy efficiency is counter balanced by increased comfort and changed heating practices. These results have to be taken into account when making long-term energy planning for a sustainable energy system.

13/02212 An analysis on the energy efficiency of air-cooled chillers with water mist system

Yang, J. *et al. Energy and Buildings*, 2012, 55, 273–284.

This paper presents the effect of operating water mist system to enhance the energy efficiency of air-cooled chillers under various operating conditions. A thermodynamic model for an air-cooled chiller with twin refrigeration circuits coupled with a water mist system was developed and validated by measured operating data. The validated model was used to investigate how the thermal properties of the entering condenser air and the performance of the air-cooled chiller varied under different operating schemes with water mist pre-cooling. Under the conventional head pressure control (HPC) with a designed water mist generation rate, the coefficient of performance (COP) increased by up to 21.3%. The chiller performance could be improved further under variable condensing temperature control (CTC). Under CTC, chiller COP was increased up to 51.5% with optimal water mist generation rate. The potential energy savings of these chillers serving a representative office building in subtropical climate was evaluated, and CTC coupling with optimal water mist generation rate would reduce the annual total electricity consumption for cooling by 14.1%. The water consumption of the water mist system was comparatively small, comparing with the total water losses for an open-loop cooling tower system with equivalent heat rejection capacity.

13/02213 An experimental comparison of two heat exchangers used in wastewater source heat pump: a novel dry-expansion shell-and-tube evaporator versus a conventional immersed evaporator

Shen, C. *et al. Energy*, 2012, 47, (1), 600–608.

A novel dry-expansion shell-and-tube evaporator (DESTE) integrated with function of defouling was developed as a component of wastewater source heat pump (WWSHP). To compare the performance of the DESTE-WWSHP with the conventional immersed evaporator (IE) based wastewater source heat pump (IE-WWSHP), an experimental platform was built by installing a DESTE and an IE unit in parallel in a same WWSHP system. The performance tests were conducted with the wastewater collected from downstream of a commercial sauna centre in Shenzhen, China. Several operating parameters were investigated, including water heating capacity, coefficient of performance (COP), hot water temperature settings, wastewater discharge rate/pattern, and hot water discharge mode (continuous or intermittent). Results showed that the DESTE-WWSHP delivered comparable heat transfer performance to the IE-WWSHP, and thus, could serve as a replacement for the latter design. Specifically, the water temperature in the water storage tank was more uniformly distributed in the DESTE-WWSHP than the IE-WWSHP; the DESTE-WWSHP exhibited higher water heating capacity than the IE-WWSHP in the continuous hot water discharge mode. The DESTE has a heat transfer coefficient 3.1 times higher than that of the IE unit on the wastewater side. At the same heating capacity, the DESTE was far more compact with its compactness seven times higher and its volume 91.71% smaller than the IE unit, leading to considerable savings in room space and materials. Additional benefits offered by this DESTE-WWSHP included reduced labour and power costs for cleaning heat exchanger, and decreased odour nuisance.

13/02214 Creep-fatigue damage evaluation of sodium to air heat exchanger in sodium test loop facility

Lee, H.-Y. *et al. Nuclear Engineering and Design*, 2012, 250, 308–316.

A high temperature design and evaluation of creep-fatigue damage for a sodium-to-air heat exchanger, AHX, has been conducted according to the recent versions of the high temperature design codes based on a full three-dimensional finite element analysis. AHX is a shell- and tube-type heat exchanger with 36 helical tubes, and has an outer diameter of 1.59 m and height of 6.5 m. AHX was installed in a sodium test loop facility, STELLA (Sodium integral effect test loop for safety simulation and assessment) recently constructed at the KAERI site. The materials of the shell and tube in AHX are 304SS and 316SS, respectively. Evaluations of creep-fatigue damage based on 3D finite element analyses were conducted at several critical locations of AHX according to the recent elevated temperature design codes of ASME-NH and RCC-MR, and the evaluation results of the two codes were compared. The present design of the AHX was shown to be acceptable in terms of creep-fatigue damage according to the two codes. The highest stress intensity (SI) under secondary loading was calculated to be 279.88 MPa at the lower joint part of the inner shell to the tubesheet, while the maximum SI at the tubesheet was 153.05 MPa, which means that the stress level of the tubesheet is not high as reported in the papers based on the simplified two-dimensional analysis. The creep-fatigue damage for the AHX under the specified thermal transient conditions was calculated to be very low. When comparing creep-fatigue damage according to the two design codes, ASME-NH was shown to be more conservative in fatigue damage while RCC-MRx was more conservative in creep damage for the present sodium-to-air heat exchanger.

13/02215 Criteria for performance improvement of a molten salt thermocline storage system

Yang, X. *et al. Applied Thermal Engineering*, 2012, 48, 24–31.

Thermal energy storage is considered to be an important subsystem for solar thermal power stations because of the fluctuations in sunshine over time. A molten salt thermal storage tank contains thermally stratified fluid, with hot temperature on the upper level and cold temperature in the lower level. Although a few studies have explored molten salt thermocline energy storage for solar thermal plants, the criteria for performance improvement are still not understood adequately. To this end, this paper summarizes four criteria for describing the performance of a molten salt thermocline energy storage system. The criteria emphasize different aspects of the storage process, including thermal storage capacity, entropy generation, efficiency η_1 based on outlet temperature, and efficiency η_2 based on thermocline thickness. The effects of the physical properties of different filler materials on the performance are also discussed. The findings indicate that filler particles with higher density, higher specific heat, lower diameter, lower thermal conductivity, and lower porosity should be selected to increase thermal storage capacity and efficiency. However, increasing the density and specific heat will also lead to higher entropy generation in the system.

13/02216 Development of non-deform micro-encapsulated phase change energy storage tablets

Darkwa, J. *et al. Applied Energy*, 2012, 98, 441–447.

This study evaluates the concept of developing a non-deform phase change energy storage material possessing higher thermal conductivity and energy storage density through pressure compaction process. The theoretical and experimental investigations have shown that the technique is able to reduce porosity and increase conductivity and energy storage density of a composite material. Even though there was some measure of plastoelasticity due to decompression, the average porosity was reduced from 62% to 23.8% at a relatively low compaction pressure of 2.8 MPa without any structural damage to the tested sample. The mean energy storage density increased by 97% and the effective thermal conductivity also increased by 25 times despite 10% reduction in its latent heat capacity. There is however the need for further development towards minimizing the effect of decompression and achieving stronger energy storage tablets at relatively low compaction force.

13/02217 Effect of copper coating on infiltrated PCM/foam

Almajali, M. *et al. Energy Conversion and Management*, 2013, 66, 336–342.

Experimental study was performed to investigate the effect of copper coating on the thermal performance of encapsulated phase change material/carbon foam composite (hybrid foam). Two types of carbon foam materials were used namely, pristine and copper-coated carbon foams. Both foams were infiltrated with paraffin wax. The temperature distribution within hybrid foam was monitored experimentally using constant heat load setup. Copper-coated carbon foam shows excellent results compared to the pristine foam. Within the coating foam; the time required to reach the melting temperature was shorter and the heat transferred faster. Further, copper coating process enhanced the overall thermal conductivity of the composite by a factor of 1.67 compared to the pristine foam.

13/02218 Effect of moisture content on heat and moisture transport and storage properties of thermal insulation materials

Jerman, M. and Černý, R. *Energy and Buildings*, 2012, 53, 39–46.

Computational models of heat and moisture transport are frequently used in calculating energy gains and losses in buildings. However, any model can provide reliable information only in the case that the quality of input data is adequate. This is not always true because the standard lists of thermal and hygric parameters given by the producers as well as the material databases included in the simulation tools are usually far from complete. This paper presents the measurements of complete sets of heat and moisture transport and storage parameters of selected thermal insulation materials in dependence on moisture content. Two common thermal insulation materials, namely hydrophobic mineral wool and expanded polystyrene, are selected as reference materials. Two types of hydrophilic mineral wool and an autoclaved-aerated-concrete thermal insulation board are the representatives of prospective materials which appeared on the market within the last couple of years. The studied material parameters include bulk density, matrix density, porosity, saturation moisture content, thermal conductivity, specific heat capacity, moisture diffusivity, water vapour diffusion coefficient, sorption isotherm, and water retention curve.

13/02219 Effectiveness of CFD simulation for the performance prediction of phase change building boards in the thermal environment control of indoor spaces

Gowreesunker, B. L. and Tassou, S. A. *Building and Environment*, 2012, 59, 612–625.

This paper reports on a validation study of computational fluid dynamics (CFD) models used to predict the effect of phase change materials (PCM) clay boards on the control of indoor environments, in ventilated and non-ventilated situations. Unlike multi-zonal models, CFD is important in situations where localized properties are essential such as in buildings with complex and large geometries. The employed phase change model considers temperature/enthalpy hysteresis and varying enthalpy–temperature characteristics to more accurately simulate the phase change behaviour of the PCM boards compared to the standard default modelling approach in the commercial CFD codes. Successful validation was obtained with a mean error of 1.0 K relative to experimental data, and the results show that in addition to providing satisfactory quantitative results, CFD also provides qualitative results which are useful in the effective design of indoor thermal environment control systems utilizing PCM. These results include: (i) temperature and air flow distribution within the space resulting from the use of PCM boards and different night ventilation rates; (ii) the fraction of PCM experiencing phase change and is effective in the control of the indoor thermal environment, enabling optimization of the location of the boards; and (iii) the energy impact of PCM boards and adequate ventilation configurations for effective night charging.

13/02220 Effects of intergranular gas bubbles on thermal conductivity

Chockalingam, K. *et al. Journal of Nuclear Materials*, 2012, 430, (1–3), 166–170.

Model microstructures obtained from phase-field simulations are used to study the effective heat transfer across bicrystals with stationary grain boundary bubble populations. It was found that the grain boundary coverage, irrespective of the intergranular bubble radii, is the most relevant parameter to the thermal resistance, which is used to derive effective Kapitza resistances that are dependent on the grain boundary coverage and Kaptiza resistance of the intact grain boundary. This study proposes a model to predict thermal conductivity as a function of porosity, grain-size, Kaptiza resistance of the intact grain boundary, and grain boundary bubble coverage.

13/02221 Electrically conductive carbon nanofiber/paraffin wax composites for electric thermal storage

Zhang, K. *et al. Energy Conversion and Management*, 2012, 64, 62–67.

The research of electric thermal storage (ETS) has attracted a lot of attention recently, which converts off-peak electrical energy into thermal energy and release it later at peak hours. In this study, new electric thermal storage composites are developed by employing paraffin wax as thermal storage media and carbon nanofibre (CNF) as conductive fillers. Electric heating and thermal energy release performances of the CNF/paraffin wax composites are experimentally investigated. Experimental results show that, when the composites are heated to about 70 °C, the developed electrically conductive CNF/paraffin wax composites present a thermal storage capacity of about 280 kJ/kg, which is five times of that of traditional thermal storage medium such as ceramic bricks (54 kJ/kg). The CNF/paraffin wax composites can also effectively store the thermal energy and release the thermal energy in later hours.

13/02222 Electrohydrodynamic natural convection enhancement for horizontal axisymmetric bodies

Marucho, M. and Campo, A. *International Journal of Thermal Sciences*, 2013, 63, 22–30.

This article addresses a new theoretical derivation to describe the electrohydrodynamic (EHD) natural convection enhancement for isothermal, horizontal axisymmetric bodies immersed in a dielectric liquid under the effects of uniform electric fields. Using asymptotic power series expansions in the laminar boundary-layer regime, convenient explicit relations are obtained which are capable of predicting the local and average Nusselt numbers in terms of two controlling parameters, namely the Rayleigh number and the electric Rayleigh number. The solutions of two coupled partial differential equations for the temperature and the stream function are represented by Gortler-type series, which are universal with respect to body contours. The Gortler-type series appears to converge rapidly so that minimal computational effort is required even for a sub-class of body shapes that do not admit the usual similarity transformations. As an example, the leading order approximation for the first derivative of the temperature is used to calculate the local and total average Nusselt numbers for horizontal circular cylinders.

13/02223 Energetic optimization of the performances of a hot air engine for micro-CHP systems working with a Joule or an Ericsson cycle

Creyx, M. *et al. Energy*, 2013, 49, (1), 229–239.

The micro combined heat and electrical power systems (micro-CHP) with hot air engines are well adapted for solid biomass upgrading, in particular, the Ericsson engines working with an open cycle and an external combustion. This paper presents a model of an Ericsson engine with a compression and an expansion cylinder which allows a thermodynamic optimization of the engine performances in a global approach. A sensitive analysis on the influent parameters is carried out in order to determine the optimal working conditions of the engine: temperature and pressure range, expansion cycle shape with a late intake valve closing or an early exhaust valve closing, heat transfers through the wall of the cylinders. This study, focused on thermodynamic aspects, is a first step in the design of an Ericsson engine.

13/02224 Energy performance of supermarket refrigeration and air conditioning integrated systems working with natural refrigerants

Cecchinato, L. *et al. Applied Thermal Engineering*, 2012, 48, 378–391.

The current trends in commercial refrigeration aim at reducing the synthetic refrigerant charge, either by minimizing the internal volume of the circuit or by utilizing natural refrigerants, and at energy saving. The energy efficiency of supermarkets can be improved by optimizing components design, recovering thermal and refrigerating energy, adopting innovative technology solutions, integrating the HVAC system with medium temperature and low temperature refrigeration plants and, finally, reducing thermal loads on refrigerated cases. This study aims at investigating the performance of different lay-out and technological solutions where only natural refrigerants are used and at finding the potential for improving energy efficiency over the traditional systems in different climates. In the analysis, chillers and heat pumps working with ammonia or propane, medium temperature systems working with ammonia or propane and carbon dioxide as heat transfer fluid or with carbon dioxide as the refrigerant and low temperature systems working with carbon dioxide are considered and benchmarked with a state-of-the-art HFCs based plant. The most efficient investigated solution enables an annual energy saving higher than 15% with respect to the baseline solution for all the considered climates.

13/02225 Evaluation of the impacts of refrigerant charge on air conditioner and heat pump performance

Kim, W. and Braun, J. E. *International Journal of Refrigeration*, 2012, 35, (7), 1805–1814.

This paper provides results that show the impact of charge level on capacity and efficiency for several units tested in the laboratory. To evaluate the performance, capacity ratio and coefficient of performance ratio were determined from measurements at various refrigerant charge levels and operating conditions. For all systems considered in this study, a refrigerant charge reduction of 25% led to an average energy efficiency reduction of about 15% and capacity degradation of about 20%. To evaluate the economic value of charge detection and correction, seasonal energy efficiency ratio (SEER) and annual cost of electricity were determined for some case studies based on the tested units. The results imply that charging inaccuracies could cause significant decreases in SEER, leading to increases in the operating costs. When the refrigerant was charged to 75% of design, the SEER value decreased by 16% and annual operating cost was increased by US$100 per ton of capacity.

13/02226 Experimental evaluation of insulation materials for walls and roofs and their impact on indoor thermal comfort under composite climate

Kumar, A. and Suman, B. M. *Building and Environment*, 2012, 59, 635–643.

Better insulation having low thermal conductivity is a significant contributor for new construction and retrofitting existing buildings, when the emphasis is on energy efficiency. The objective of the study is to determine the impact of the thermal insulation materials in buildings enabling effective energy savings with minimal occupation of space. Although, the Energy Conservation Building Code (ECBC), India defines the prescriptive and mandatory requirements for the *U*-factor and R-value but the way to achieve these values is left to the designer and there is no published data on these values. To accomplish these objectives, the experiments for computation of thermal resistance and over all heat transfer coefficients have been carried out by measuring the thermal conductivity of the various types of materials available in the Indian market having different thicknesses by automatic guarded hot plate apparatus. One hundred and twelve combinations of wall and roof sections have been computed and compared with different thicknesses of insulating materials for determining *U*-factor and *R*-value to satisfy ECBC requirements. The results of the study show that 50 mm thick Elastospray with conventional roof and wall satisfy the ECBC requirements whereas, other insulation materials require higher thickness to fulfill the recommended values. To validate the results, two prototype buildings are constructed at CSIR–CBRI campus; one with conventional burnt clay brick wall, reinforced cement concrete roof and 50 mm thick outside thermal insulation and the other without insulation. The results of the winter and summer season for 6 months are presented.

13/02227 Experimental investigation adsorption chillers using micro-porous silica gel–water and compound adsorbent-methanol

Lu, Z. *et al. Energy Conversion and Management*, 2013, 65, 430–437.

Compound adsorbent of macro-porous silica gel/LiCl-methanol and micro-porous silica gel–water were used as working pairs in two adsorption cooling systems respectively. The adsorption performance was experimentally investigated and compared. The experiment results are that mass recovery process can improve cooling capacity significantly while heat recovery process can improve coefficient of performance (COP) more significantly. The silica gel/LiCl-methanol cooling system has higher adsorption capacity and working pressure. When the hot water inlet temperature, cooling water inlet temperature and chilled water outlet temperature are about 85, 31 and 15 °C, the specific cooling power (SCP) of silica gel/LiCl-methanol cooling system is higher by 59.5% than that of silica gel–water cooling system. The silica gel/LiCl-methanol cooling system can also work for cold storage. When the hot water inlet temperature, cooling water inlet temperature and chilled water outlet temperature are about 88, 25 and −4 °C, the cooling capacity and COP are 1.0 kW and 0.13.

13/02228 Experimental investigation of a pilot compression chiller with alternatives refrigerants using compact heat exchanger

Hassan, M. A. M. *Energy Conversion and Management*, 2013, 66, 277–284.

This paper reports the results of an experimental investigation on a pilot compression chiller working with R407C and R410A as R22 alternatives using compact heat exchanger. Experiments are conducted and the influences of the cooling water mass flow rate (200–2500 kg/h), cooling water inlet temperature (20–45 °C) and chilled water mass flow rate (200–1500 kg/h) on performance characteristics of chillers are evaluated for R22, R407C and R410A. Increasing the cooling water mass flow rate or decreasing its inlet temperature causes the operating pressures and electric input power to decrease while the cooling capacity and coefficient of performance (COP) increase. The pressure ratio is reduced while actual loads and COP are increased with the chilled water mass flow rate. The effect of cooling water inlet temperature on the system performance is more significant than the effects of cooling and chilled water mass flow rates. Comparison between R22, R407C and R410A under identical operating conditions has been done. An enhancement is obtained when using compact heat exchanger than shell and tube heat exchanger, this enhancement is about 8.5% in the coefficient of performance.

13/02229 Experimental study of friction and heat transfer characteristics in narrow rectangular channel

Wang, C. *et al. Nuclear Engineering and Design*, 2012, 250, 646–655.

This work presents an experimental investigation of the friction and heat transfer characteristics in a narrow rectangular channel. Nine groups of experiments are conducted and the fluid temperature difference between the inlet and outlet of the test section is kept constant in each experimental run. The results show that the friction factors in isothermal condition can be well correlated by the Leon correlation for the developed laminar and turbulent flow, and the Bhatti and Shah correlation for the laminar to turbulent transition region. In addition, the friction factors prediction correlations in non-isothermal condition are proposed based on the viscosity ratio method. The heat transfer characteristic is not affected by the change of temperature difference in laminar flow. However, as in the fully developed turbulent flow, the Prandtl number significantly influences the heat transfer characteristic. The heat transfer temperature difference between the wall and fluid increases with the increase of Reynolds number in the laminar flow, and decreases sharply as the flow enters the transition region. However, it does not present a significant variation in the fully developed turbulent flow regime. Based on the analysis of heat transfer temperature difference, a new correlation for calculating the Nusselt number in the turbulent flow regime of a rectangular channel is introduced and the agreement between experimental data and predicted values is satisfactory.

13/02230 Experimental study on thermophysical properties of nanofluids as phase-change material (PCM) in low temperature cool storage

He, Q. *et al. Energy Conversion and Management*, 2012, 64, 199–205.

In this article, a new sort of nanofluid phase change materials (PCMs) is developed by suspending a small amount of TiO_2 nanoparticles in saturated $BaCl_2$ aqueous solution. Its thermal conductivities, supercooling degree, latent heat, specific heat, and rheological behaviours of the nanofluids PCMs were investigated. The experimental results show that with volume fraction is 1.130%, the thermal conductivities of nanofluids PCMs is enhanced by 12.76% at −5 °C, the supercooling degree is reduced by 84.92%. The latent heat and specific heat are slightly decreased with suspending nanoparticles. The viscosity increased with the increasing volume fraction, which will have no effect on the cool storage system. The higher thermal performances of nanofluids PCMs indicate that they are suitable for the industries low temperature energy storage.

13/02231 Fabrication and performances of new kind microencapsulated phase change material based on stearic acid core and polycarbonate shell

Zhang, T. *et al. Energy Conversion and Management*, 2012, 64, 1–7.

This work is focused on the preparation, characterization and thermal properties of stearic acid/polycarbonate (SA/PC) microcapsule as a new kind of phase change material (PCM) for thermal energy storage, which was prepared by solution casting method. Its morphology, chemical structure and thermal performances were characterized by scanning electron microscope (SEM), Fourier transform infrared (FT-IR), differential scanning calorimetry (DSC), temperature curves and volume expansion coefficient, respectively. The results show that stearic acid was encapsulated successfully with the maximum mass fraction of 52% without leakage from the composite. The average diameter of microcapsule was found to be $0.50\,\mu\text{m}$. Two components of the composite PCM, SA and PC, have no chemical reaction and exhibit good compatibility with each other. The melting and freezing temperatures and the latent heats of the microcapsule were measured as 60.0 and 51.2 °C, 91.4 and 96.8 J/g, respectively. Iron filings were employed to improve thermal storage and release rates and the rates increased 23% compared with the composite without iron filings. Accelerated thermal cycling test showed that the microcapsules have good thermal reliability after subjected to 1000 thermal cycling because it has similar volume expansion coefficient of polycarbonate. Due to its excellent thermal stability and reliability and simple preparation method, the shape-stabilized SA/PC microcapsule can be considered as candidate PCM for thermal energy storage applications.

13/02232 Field measurement of albedo for different land cover materials and effects on thermal performance

Li, H. *et al. Building and Environment*, 2012, 59, 536–546.

Albedo (or solar reflectivity) plays an important role in the thermal behaviour of pavements and other ground surfaces, and their resultant impacts on humans and the environment. This study developed a new albedo measurement system with a dual-pyranometer and automatic data acquisition system, and used it to conduct field measurements of albedo on different pavement materials and for long-term monitoring of albedo. The albedo values were obtained for commonly used land cover materials including asphalt, concrete and interlocking concrete paver surfacing materials with different designs and some other materials. These new data can help reduce the uncertainty in understanding, evaluating and modelling the thermal behaviour and environmental impacts of ground surfaces with different albedos. The seasonal effects of albedo on pavement thermal performance were examined through experimental measurements. An empirical relationship between the cooling effect of increased albedo on a pavement's high temperature and solar radiation was developed. The cooling effect has a positive correlation with the peak solar radiation intensity. This simple correlation can be used to roughly estimate the cooling or heating effect of changing albedo on pavement for various climates and seasons with different solar radiation intensities.

13/02233 Heat transfer of supercritical mixtures of water, ethanol and nitrogen in a bluff body annular flow

Stathopoulos, P. *et al. The Journal of Supercritical Fluids*, 2012, 70, 112–118.

Hydrothermal spallation drilling is a promising drilling technique that could prove economically advantageous over rotary techniques for deep wells, where hydrothermal flames can provide the required heat to spall the rock. Assisted ignition of hydrothermal flames must be understood prior to the field implementation of the technology. The convective heat transfer in a burner setup has been therefore investigated, where the flow conditions are similar to those of a bluff body wake flow in annular geometry. Various ternary mixtures of water, ethanol and nitrogen were used as model working fluids to simulate the combustion conditions of water–ethanol mixtures with oxygen. Water ethanol mixtures were pre-heated between 350 and 420 °C, and nitrogen was pre-heated up to 400 °C, while the working pressure was set at 260 bar. The convective heat transfer coefficient from an electrically heated surface to the mixtures is presented.

13/02234 Mass transfer modeling in gas barrier envelopes for vacuum insulation panels: a review

Bouquerel, M. *et al. Energy and Buildings*, 2012, 55, 903–920.

A vacuum insulation panel (VIP) is a very efficient thermal insulation system for buildings. It is constituted of an evacuated porous core material, enveloped in a gas barrier membrane. The total conductivity measured is as low as 5 mW/(m K). The high performance is due to the low pressure inside the panel and the gas barrier envelope plays a key role in maintaining the vacuum during the whole VIP service life. Indeed, due to the permeation of atmospheric gases through the envelope, a slow increase of pressure and humidity occurs over time, which involves a thermal conductivity increase in the meantime. This review paper details the mass transfer models used to predict the permeation rates of gases through the VIP envelope. The sorption–diffusion model for gas permeation through polymer membranes is presented as well as alternative permeation models. The parameters which play a key role for mass transfer are detailed. The adaptation of the permeation models from homogeneous polymer membranes to multilayer gas barrier membranes is then presented, including an important section about metal-coated polymer films. The conclusions of the works based on several approaches are reported.

13/02235 Microencapsulated n-octadecane with different methylmethacrylate-based copolymer shells as phase change materials for thermal energy storage

Qiu, X. *et al. Energy*, 2012, 46, (1), 188–199.

Microcapsules containing n-octadecane with different methylmethacrylate (MMA)-based copolymer shells were fabricated by a suspension-like polymerization. Butyl acrylate (BA), butyl methacrylate (BMA), lauryl methacrylate (LMA) and stearyl methacrylate (SMA) were employed as monomers to copolymerize with MMA. Pentaerythritol tetraacrylate (PETRA) was employed as a crosslinking agent. The (microencapsulted phase change materials) MicroPCMs were characterized using Fourier transformed infrared (FTIR) spectroscopy and scanning electron microscopy (SEM). Thermal properties and thermal resistances of MicroPCMs were investigated by differential scanning calorimetry (DSC) and thermal gravimetric analysis (TGA), respectively. Phase change enthalpies and PCM contents of MicroPCMs increased with the length decreasing of the side chain of the monomers. The n-octadecane content of as much as 77.3% can be obtained in the crosslinked MicroPCMs with P(MMA-co-BMA) as shell, and accompanied by the highest melting enthalpy (173.7 J/g) and crystallization enthalpy (174.4 J/g). Heat capacities of crosslinked MicroPCMs are higher than those of their uncrosslinked counterparts. The crosslinked MicroPCMs exhibit significantly greater thermal stabilities compared with their uncrosslinked counterparts and the n-ontadecane bulk. The crosslinked MicroPCMs with P(MMA-co-SMA) displays the highest thermal resistance temperature up to 255 °C. Therefore, MicroPCMs with MMA-based copolymer as shells, especially crosslinked copolymer shells, show excellent potentials for thermal energy storage.

13/02236 Molecular dynamics simulations of melting behavior of alkane as phase change materials slurry

Rao, Z. *et al. Energy Conversion and Management*, 2012, 64, 152–156.

The alkane based phase change materials slurry, with high latent heat storage capacity, is effective to enhance the heat transfer rate of traditional fluid. In this paper, the melting behaviour of composite phase change materials slurry which consists of *n*-nonadecane and water was investigated by using molecular dynamics simulation. Four different systems including pure water and water/*n*-nonadecane composite were constructed with amorphous structure and periodic boundary conditions. The results showed that the simulated density and melting temperature were very close to the published experimental values. Mixing the *n*-nonadecane into water decreased the mobility but increased the energy storage capacity of composite systems. To describe the melting behaviour of alkane based phase change materials slurry on molecular or atomic scale, molecular dynamics simulation is an effective method.

13/02237 Optimal control of building storage systems using both ice storage and thermal mass – part I: simulation environment

Hajiah, A. and Krarti, M. *Energy Conversion and Management*, 2012, 64, 499–508.

This paper presents a simulation environment that can evaluate the benefits of using simultaneously building thermal capacitance and ice storage system to reduce total operating costs including energy and demand charges while maintaining adequate occupant comfort conditions within commercial buildings. The building thermal storage is controlled through pre-cooling strategies by setting space indoor air temperatures. The ice storage system is controlled by charging the ice tank and operating the chiller during low electrical charge periods and melting the ice during on-peak periods. Optimal controls for both building thermal storage and ice storage are developed to minimize energy charges, demand charges, or combined energy and demand charges. The results obtained from the simulation environment are validated using laboratory testing for an optimal controller.

13/02238 Optimal controls of building storage systems using both ice storage and thermal mass – part II: parametric analysis

Hajiah, A. and Krarti, M. *Energy Conversion and Management*, 2012, 64, 509–515.

This paper presents the results of a series of parametric analysis to investigate the factors that affect the effectiveness of using simultaneously building thermal capacitance and ice storage system to reduce total operating costs (including energy and demand costs) while maintaining adequate occupant comfort conditions in buildings. The analysis is based on a validated model-based simulation environment and includes several parameters including the optimization cost function, base chiller size, and ice storage tank capacity, and weather conditions. It found that the combined use of building thermal mass and active thermal energy storage system can save up to 40% of the total energy costs when integrated optimal control are considered to operate commercial buildings.

13/02239 Reduced-scale study of wind influence on mean airflows inside buildings equipped with ventilation systems

Le Roux, N. *et al. Building and Environment*, 2012, 58, 231–244.
To study mass transfers inside buildings equipped with ventilation systems, a methodology has been developed to carry out reduced-scale experiments for studying isothermal flows in a steady or a transient state. This methodology has been numerically and experimentally validated on simple configurations and applied to two reference configurations representative of nuclear facilities. The wind influence on mass transfers inside these configurations, in nominal, damaged (ventilation stopped) or accidental (internal overpressure) situations, has been studied by carrying out wind tunnel experiments. The objectives of this article are to present the scaling-down methodology and the main experimental results concerning the influence of wind on steady-state airflows inside the reduced-scale models. It is notably shown that wind effects can lead to a partial or a total loss of the pollutant containment inside buildings. The reliability of the zonal code SYLVIA, which is used to support safety assessments in nuclear facilities, has then been analysed from these experimental results.

13/02240 Refrigerating liquid prototype for LED's thermal management

Faranda, R. *et al. Applied Thermal Engineering*, 2012, 48, 155–163.
The heat management is the critical factor for high-performance operation of light-emitting diodes (LED). A new heat management application of refrigerating liquid integrated within a fabricated prototype is proposed and investigated. A series of experiments considering different heights of liquid level were performed to evaluate the heat dissipation performance and optical characteristics of the refrigerating liquid based prototype. The results reveal that the junction temperature decreases as the level of refrigerating liquid increases. The experimental results report that the refrigerating liquid reduces the junction temperature, and can positively influence the luminous radiation performances. An optimization investigation of the proposed solution was carried out to find an optimum thermal performance. The experiments indicated that refrigerating liquid cooling is a powerful way for heat dissipation of high-power LEDs, and the fabrication of prototype was feasible and useful.

13/02241 Review on phase change materials (PCMs) for cold thermal energy storage applications

Oró, E. *et al. Applied Energy*, 2012, 99, 513–533.
Thermal energy storage (TES) is a technology with a high potential for different thermal applications. It is well known that TES could be the most appropriate way and method to correct the gap between the demand and supply of energy and therefore it has become a very attractive technology. In this paper, a review of TES for cold storage applications using solid–liquid phase change materials has been carried out. The scope of the work was focused on different aspects: phase change materials (PCMs), encapsulation, heat transfer enhancement, and the effect of storage on food quality. Materials used by researchers as potential PCM at low temperatures (less than 20 °C) are summarized and some of their thermophysical properties are reported. Over 88 materials that can be used as PCM, and about 40 commercially available PCM have been listed. Problems in long term stability of the materials, such as corrosion, phase segregation, stability under extended cycling or subcooling are discussed. Heat transfer is considered both from theoretical and experimental point of view and the different methods of PCM encapsulation are reviewed. Many applications of PCM at low temperature can be found, such as, ice storage, conservation and transport of temperature sensitive materials and in air conditioning, cold stores, and refrigerated trucks.

13/02242 Simulation study on supply temperature optimization in domestic heat pump systems

Huchtemann, K. and Müller, D. *Building and Environment*, 2012, 59, 327–335.
An air-to-water heat pump system for the heating of a one-family home is numerically analysed. The influence of the supply temperature on the seasonal performance factor of the heating system is examined by varying the heating curve. Furthermore, an adaptive control algorithm is studied which lowers the supply temperature according to the actual heating demand. The study includes a variation of control parameters. The different configurations are evaluated with respect to their efficiency (seasonal performance factor) and the comfort (room temperature). In systems with correctly parametrized heating curve controlling the room temperature is likely to be too high because of inner loads and solar gains. Instead of dealing with these gains by lowering the mass flow using thermostatic valves, the supply temperature can be dropped. This has a positive effect on heat pump efficiency because it decreases the total temperature lift. The control algorithm adapts the supply temperature in discrete time steps depending on the position of the thermostatic valve. Special attention has to be paid for the resulting room temperature and its deviation. With the control algorithm presented in this paper, the seasonal performance factor can be increased by up to 0.19, depending on the allowed variability of room temperature. Savings in annual primary energy demand compared to a standard controlling are up to 6.8%.

13/02243 Simulation study on the performance of solar/natural gas absorption cooling chillers

Gomri, R. *et al. Energy Conversion and Management*, 2013, 65, 675–681.
Solar radiation is a clean form of energy and solar cooling systems is one of the technologies which allow obtaining an important energy saving. Natural gas is a cheaper fuel than oil. It also burns cleaner than oil. Natural gas and renewable energy are complementary and in the future, the alignment of natural gas and renewable energy may be the most effective way to service the demand for clean energy. This paper presents a numerical study of solar/natural gas single effect lithium bromide absorption chillers. The development of this system is based on hot water chiller. As auxiliary power, fire from the natural gas burners is used to heat the hot water on its way to the generator. The overall performance of the absorption chiller system is analysed and discussed. For an evaporator temperature of 5 °C and when the condenser temperature is varied from 28 to 36 °C and generator temperatures is varied from 54 to 83 °C the maximum COP is 0.82 and the maximum exergetic efficiency is about 30%. For a given condenser temperature there is an optimum generator temperature for which the number of flat plate collectors is minimum. This optimum generator temperature corresponds to the generator temperature giving the maximum COP and exergy efficiency of the absorption cooling system. The solar/natural gas single effect lithium bromide absorption chillers, using solar energy as the energy source with only limited amount of gas as auxiliary power, not only reduces greatly the cost for electricity and operates in regions where there are abundant solar energy and cheap natural gas resources, but also compensates the peak-valley load difference and reduce CO_2 gas emissions. For a refrigeration capacity of 10 kW, the quantity of natural gas used to provide auxiliary load is very small and consequently the CO_2 gas emissions is very small (the maximum mass flow rate of CO_2 is less than $3\,kg\,h^{-1}$).

13/02244 State of the art on phase change material slurries

Youssef, Z. *et al. Energy Conversion and Management*, 2013, 65, 120–132.
The interest in using phase change slurry (PCS) media as thermal storage and heat transfer fluids is increasing and thus leading to an enhancement in the number of articles on the subject. In air-conditioning and refrigeration applications, PCS systems represent a pure benefit resulting in the increase of thermal energy storage capacity, high heat transfer characteristics and positive phase change temperatures which can occur under low pressures. Hence, they allow the increase of energy efficiency and reduce the quantity of thermal fluids. This review describes the formation, thermophysical, rheological, heat transfer properties and applications of four PCS systems: clathrate hydrate slurry, microencapsulated phase change material (PCM) slurry, shape-stabilized PCM slurries and PCM emulsions. It regroups a bibliographic summary of important information that can be very helpful when such systems are used. It also gives interesting and valuable insights on the choice of the most suitable PCS media for laboratory and industrial applications.

13/02245 Study on the cool roof effect of Japanese traditional tiled roof: numerical analysis of solar reflectance of unevenness tiled surface and heat budget of typical tiled roof system

Takebayashi, H. *et al. Energy and Buildings*, 2012, 55, 77–84.
To assess the effect of uneven tiled surfaces on solar reflectance, a numerical calculation was utilized to estimate the solar reflectance of several kinds of surface shapes. In addition, the relationship between solar reflectance of uneven surfaces and surface shapes was analysed. Drawing on the calculation results, the reduction of solar reflectance from the flat surface was also estimated. A heat budget model of the tile surface and sectional direction of the roof system was developed on the basis of observation results relating to the thermal characteristics of a traditional tiled roof system. A comparative simulation with other urban heat island mitigation technologies, such as green roofs, was carried out under typical weather conditions.

13/02246 The interaction of rivers and urban form in mitigating the urban heat island effect: a UK case study

Hathway, E. A. and Sharples, S. *Building and Environment*, 2012, 58, 14–22.
The urban heat island (UHI) effect already produces elevated temperatures in city centres therefore urban design has a key role to pay in reducing the UHI to create safe and pleasant places in which to

live and work. Increased surface porosity and bodies of surface water have a role to play in increasing potential cooling through evaporation. Urban rivers may, therefore, have a place in reducing the UHI. This paper investigates the effectiveness that small urban rivers may have in reducing the UHI effect and also examines the role that the urban form on the banks of a river can play in propagating or reducing this potential cooling. The results from a field survey during spring and summer are presented for a river in Sheffield, UK. The level of cooling is related to the ambient air temperature, increasing at higher temperatures. However, there are also seasonal dependencies and relationships linked to the river water temperature, incident solar radiation, wind speed and relative humidity. A mean level of daytime cooling of over 1.5 °C was found above the river in spring, but this was reduced in summer when the river water temperature was warmer. The urban form on the river bank influenced the levels of cooling felt away from the river bank.

13/02247 The role of cool thermal energy storage (CTES) in the integration of renewable energy sources (RES) and peak load reduction

Ban, M. *et al. Energy*, 2012, 48, (1), 108–117.

The building sector is one of the largest energy consumers. Even though cooling needs do not contribute a large share to the overall energy demand in temperate climates, recent trends show a tendency of large growth. This growth is related to two main drivers: cheap and affordable air-conditioning units that have overrun the market and the more frequent occurrence of hot and extremely hot weather conditions. In combination with inadequate insulation and sealing in most old buildings, both drivers contributed to new cooling installations that are significantly increasing electricity demand and peak load, even at the national level. Consequently, the use of fossil fuels in power plants and electricity import has increased. The development of sustainable buildings and the use of renewable energy sources (RES) seem to be promising solutions. However, the problem of the integration of RES in the current energy system is related to their intermittent nature and uncontrollable occurrence. Cool thermal energy storage (CTES) may play an important role in the management of peak loads and solve the intermittency problem of RES, especially when cooling storage is integrated into district cooling systems. A simple mathematical model of a system with integrated RES and CTES has been developed. Hourly system analyses have been conducted for one building, a group of buildings connected to the district cooling system and a region represented by a mixture of different demands for cool thermal energy. This paper also includes the results for the overall energy efficiency, cost effectiveness and environmental impact of the systems analysed.

13/02248 Thermodynamic and kinetic investigation of a chemical reaction-based miniature heat pump

Flueckiger, S. M. *et al. Energy Conversion and Management*, 2012, 64, 222–231.

Representative reversible endothermic chemical reactions (paraldehyde depolymerization and 2-proponal dehydrogenation) are theoretically assessed for their use in a chemical heat pump design for compact thermal management applications. Equilibrium and dynamic simulations are undertaken to explore the operation of the heat pump which upgrades waste heat from near room temperature by approximately 20° in a minimized system volume. A model is developed based on system mass and energy balances coupled with kinetic equations to ascertain mixture conditions at each state point in the loop, as well as mass flow rate, minimum work input, and minimum endothermic reactor volume according to defined reservoir temperatures and desired heat load. Assuming that a pervaporation process is employed in both reaction systems to achieve the requisite mixture compositions for sustained operation, the simulations show that the chemical heat pump can pump 5 W of power with endothermic reactor volumes of as little as 60–93 cm^3, depending on the selected chemical reaction. Low exergy efficiencies remain a significant design consequence, but the system performance in terms of environmental impact and COP are comparable with, and in some cases better than, the performance of alternative technologies under the same conditions.

13/02249 Thermoelectric energy harvesting from diurnal heat flow in the upper soil layer

Whalen, S. A. and Dykhuizen, R. C. *Energy Conversion and Management*, 2012, 64, 397–402.

In this study a subterranean thermoelectric power source built and tested that converts diurnal heat flow through the upper soil layer into electricity. This paper describes the operation, design, and performance of the device. Key features of the power source include the use of bismuth-telluride thermopiles optimized for small ΔT and aerogel insulation to minimize thermal losses. The device weighs 0.24 kg and was designed with a flat form factor measuring $12 \times 12 \times 1.7$ cm to facilitate modularity, packing, and assembly into larger arrays. One full year of field testing was performed between June 2009 and May 2010 in Albuquerque, New Mexico where the device generated an average power output of 1.1 mW. The season with the highest performance was spring (March–May) while the season of lowest performance was winter (November–January). During May 2010, the device generated an average power of 1.5 mW and a peak power of 9.8 mW at 9.3 V. Ten years of continuous operation at 1.1 mW would yield an energy density and specific energy of 1384 W h/L and 1430 W h/kg, respectively, which is competitive with chemical batteries and is orders of magnitude greater than published subterranean and ambient thermoelectric harvesters. Numerical simulations show that performance is sensitive to the thermal properties of the soil and environmental conditions. This class of energy harvester may provide an option for supplemental power, or possibly primary power, for low power remote sensing applications.

13/02250 Treatment of natural stones with phase change materials: experiments and computational approaches

Romero-Sánchez, M. D. *et al. Applied Thermal Engineering*, 2012, 48, 136–143.

The treatment of natural stones with phase change materials (PCMs) is experimentally and computationally investigated with respect to developing innovative products with thermal energy storage properties. The objective is to improve the thermal properties of natural stone by exploiting associated latent heat storage phenomena. As a consequence, natural stone treated with PCMs could be used as a construction material with the ability to store thermal energy leading to reduction of the overall buildings' energy consumption. In order to demonstrate the effectiveness of this concept, a series of experiments has been performed. At first, measurements were focused on the PCM influence at the natural stone thermal properties at sample scale. At product scale, a number of 'model' concrete pilot houses have been constructed. The pilot houses were covered with trans-ventilated façade design using the Spanish 'Bateig azul' natural stone. Two cases have been examined, with and without PCM integrated in the natural stone façade. Variations of indoor temperatures have been monitored for several day–night cycles showing that a smoother indoor temperature profile is obtained when PCMs are implemented. An improvement in human comfort and a reduction of energy consumption can thus be anticipated. Furthermore, a composite computational model based on the linking of TRNSYS platform to a MATLAB subroutine is introduced. The performance of the tool is evaluated with respect to the aforementioned measurements. It is shown that a good agreement between computational results and experimental data can be achieved. Parametric studies focused on the PCM influence, highlighting the advantages of the combined experimental and computational approaches.

13/02251 Unconstrained melting inside a sphere

Hosseinizadeh, S. F. *et al. International Journal of Thermal Sciences*, 2013, 63, 55–64.

This paper presents both numerical and experimental investigations on unconstrained melting of phase change material (PCM) using *n*-octadecane inside a spherical container. Experimental studies are performed for three different wall temperatures of the container at 35, 40 and 45 °C with the PCM at an initial sub-cooling of 1 °C below the melting temperature. Numerical simulations are performed for axisymmetric melting of PCM inside a sphere using Fluent 6.3 software. After validating the numerical results with the experimental data, the effect of shell diameter on melting at different Stefan numbers is studied numerically. The results indicate that the melting rate is high at the beginning of melting due to perfect contact between the hot shell and solid PCM. The melting rate reduces with progressing time when a layer of molten PCM is formed between the shell and solid PCM. After this stage, the effect of conduction heat transfer diminishes and restricted to the bottom of sphere where the solid PCM sinks. At both sides of the sphere, convection heat transfer in the liquid PCM becomes the dominant mode for melting.

13/02252 Use of ultrasonic waves in sub-cooled boiling

Bartoli, C. and Baffigi, F. *Applied Thermal Engineering*, 2012, 47, 95–110.

This work focuses on the use of ultrasounds in heat transfer fields. Under particular conditions, ultrasonic waves induce a convection coefficient increase. This initial research work, indicates that there are some practical applications in the cooling of the latest generation electronic components. In the first part of this paper, some background on this subject is reported. The ultrasound's influence on heat transfer rate has been observed since the 1960s: different authors studied the cooling effect due to ultrasonic waves from different heat transfer regimes. The most investigated configuration was a thin platinum wire immersed in water. Later, a bibliographic research on possible practical applications of ultrasounds was carried out. This research focused in particular on the issue for three-dimensional highly integrated electronic components. For these systems the thermal problem is a major challenge, because they cannot exceed critical temperatures, after which they could be damaged irreversibly. On the basis of the experimental results, ultrasounds could represent a valid means to overcome these thermal problems. Finally, the paper presents a series of experiments performed in the Thermal-Fluid-Dynamic Lab at the Energy and Engineering Systems Department of the University of Pisa. The experiments provide systematic evidence of ultrasonic waves effects, on free convection heat transfer, from a heated circular cylinder to sub-cooled water, at atmospheric pressure. Many variables involved in the heat transfer rise were tested, for example: the ultrasonic generator's power, the position of the heater inside the ultrasonic tank, the variation of the water sub-cooling degree, as function of the heat flux needed dissipating. The aim of the experiment was to find out the set of optimal conditions, in order to successively apply all the results to real packaging systems, as mentioned before. The maximum increase in the heat transfer coefficient, due to ultrasonic waves, was 57%.

13/02253 Visualized flow structure around and inside of one-sided wind-catchers

Esfeh, M. K. *et al. Energy and Buildings*, 2012, 55, 545–552.

In this study, smoke visualization approach was used to investigate the main flow features around and inside various types of one-sided wind-catcher models. Wind-catcher models with flat, inclined or steep and curved roofs are used in the experimental flow measurement and flow visualization. Wind-catchers play an important role in creating natural ventilation and providing the thermal comfort for interior living spaces of various buildings. One-sided wind-catchers are used in locations where wind flows in predominantly known direction. In this type of wind-catchers, the tower has opening on one side only to capture wind and guide it into the building. By using smoke visualization techniques, detailed flow characteristics are revealed around and inside of typical one-sided wind-catchers. In order to examine the performance of wind-catchers quantitatively, induced airflow rate and pressure coefficients around internal surfaces of wind-catcher channel are also measured. Based on the visualized flow and measured quantities, it is shown that the flow pattern inside the wind catcher channel was strongly influenced by the geometry of wind-catcher roof. Test results show that the wind catcher with a curved roof is capable of capturing higher airflow and hence exhibits superior passive ventilation performance in comparison with the other two types.

11 ENGINES

Power generation and propulsion, electrical vehicles

13/02254 Combustion and emissions of 2,5-dimethylfuran addition on a diesel engine with low temperature combustion

Zhang, Q. *et al. Fuel*, 2013, 103, 730–735.

Biomass is the largest and most important renewable energy option at present. Because of similar physicochemical properties to gasoline and improved production methods, 2,5-dimethylfuran (DMF) has drawn extensive attention of global researchers. But currently, little investigations have been carried out on DMF as the engine fuel, especially on CI engines. In this paper, effects of DMF addition on combustion and emissions were investigated on a modified single cylinder heavy-duty diesel engine with low temperature combustion, and the characteristics of DMF and gasoline were compared specially. The results show that when DMF fraction is up to 40%, the trade-off relationship between NO_x and soot disappears and soot emissions are close to zero. DMF addition has little effects on CO and THC emissions. Although the physicochemical properties of DMF and gasoline are similar, due to the difference of ignition delay and DMF is oxygenated, it makes a great difference in combustion and emission characteristics.

13/02255 Cycle-skipping strategies for pumping loss reduction in spark ignition engines: an experimental approach

Yüksek, L. *et al. Energy Conversion and Management*, 2012, 64, 320–327.

Spark ignition (SI) engines are widely used for power generation, especially in the automotive industry. SI engines have a lower thermal efficiency than diesel engines due to a lower compression ratio, higher charge-induction work and lower end of compression stroke pressure. A significant amount of charge induction work is lost when an SI engine runs under partial loading conditions. Under partial loading conditions, a lower intake charge is required, which can be theoretically achieved by varying the displacement volume or the stroke number of the engine without using a throttle. Reducing the displacement volume to control the engine load can be achieved by skipping cycles in single-cylinder engines. This study investigates the effect of cycle-skipping strategies on the brake specific fuel consumption (BSFC) and exhaust emissions of an SI engine under partial loading conditions. Three different skipping modes were applied: normal, normal-skip and normal-normal-skip. A significant improvement in BSFC and carbon monoxide emission was obtained by applying cycle-skipping strategies.

13/02256 Development of a gas turbine fuel nozzle for DME and a design method thereof

Lee, M. C. and Yoon, Y. *Fuel*, 2012, 102, 823–830.

Dimethyl ether (DME, CH_3OCH_3) is a potentially attractive fuel for gas turbines because of low pollutant emission and easy transportation and storage. However, the high flame speed and a low ignition temperature of DME present a high risk of flash-back, which can be a potentially serious problem. To solve this problem and achieve better combustion performance, the present study contrived a new fuel nozzle for DME that can obtain optimal combustion of DME in the gas turbine combustor, thereby achieving cost reduction of power generation, enhancement in reliability of power plants and diversification of usable fuel. The configuration of a fuel nozzle for DME and a design method using Wobbe Index are both described in detail. The combustion performance of the newly developed DME fuel nozzle was verified through a gas turbine combustion test and the results showed considerable improvement in the performance of NO_x and CO emissions and the prevention of flash-back.

13/02257 Factors influencing the number distribution and size of the particles emitted from a modern diesel vehicle in real urban traffic

Barrios, C. C. *et al. Atmospheric Environment*, 2012, 56, 16–25.

Particle emissions from diesel engine cars depend firstly on exhaust aftertreatment systems but the use of the vehicle becomes also crucial. In urban areas, this use depends on: transport demand, route choices, traffic density, street conditions, weather, driver behaviour and topographical characteristics of the roads. Nowadays, most diesel vehicles in urban areas across Europe are equipped with exhaust aftertreatment systems aiming to reduce the total mass of emitted particles. In comparison to earlier aftertreatment systems, the implementation of modern procedures is causing a reduction in the size of the emitted particles up to a nanometric range. The main goal of this work is the characterization of particle size and number distribution in the submicrometric range from a modern diesel vehicle emission in real traffic conditions in the city of Madrid with the purpose of assessing the actual weight of the different city parameters influencing the particle emission. In order to accomplish this objective, up to 12 on board emission measurement experiments have been performed with a Euro IV diesel passenger car driving along a single urban circuit in Madrid City. To cover the main external factors, stretch, traffic conditions and driving directions have been considered as independent variables for this study. Assuming a proper car operating conditions, the results show that street characteristics, vehicle density and topographic features are the main factors conditioning the particle emission. Extrapolating the results, a diesel standard passenger car circulating across a city like Madrid can emit more nanoparticles per kilometre (up to 114% more in this study) at peak hour than at off peak hour. Moreover, the driving direction can also influence dramatically the emission of nanoparticles per second. This difference in the emission rate depends on the street but in this study it can be higher than 110% depending on the driving direction.

13/02258 Investigating the potential for using a simple water reaction turbine for power production from low head hydro resources

Date, A. *et al. Energy Conversion and Management*, 2013, 66, 257–270.

In this analysis the simple reaction water turbine known as Barker's Mill is revisited. It is shown that the maximum torque produced by the machine is developed when the turbine is stationary. At this point the net output power is zero. As the load torque is decreased the turbine rotates and power is produced. Furthermore, because of a centrifugal pumping effect, the mass flow rate of water through the turbine increases during acceleration. Further decrease in the load torque is accompanied by increases of speed, output power, water mass flow rate and efficiency. It is shown that when the load torque is reduced towards half the value of the torque at the stationary condition, water mass flow rate, rotational speed and output power tend towards infinity. Under this condition the efficiency of the machine approaches unity. The non-dimensional characteristics of the idealized turbine are used to investigate the general characteristics of the machine and to explore its application for production of power from water reservoirs with low heads. Theoretical analysis of a simple reaction turbine is presented including consideration of the fluid frictional losses for a practical situation. A practical turbine will never run away towards infinite speed and the maximum power and efficiency of such a turbine will depend on the fluid frictional losses. Here a new factor is defined, representing the overall fluid frictional losses within the turbine. Finally this paper presents experimental performance results for two simple reaction water turbine prototypes. The two turbine prototypes under investigation have rotor diameters 0.24 and 0.12 m, respectively. The two turbine models were tested under supply heads ranging from 1 to 4 m. The simple reaction water turbine can operate under very low hydrostatic head with high energy conversion efficiency. This type of turbine exhibits prominent self-pumping ability at high rotational speeds. Under low head to achieve high rotational speeds the turbine diameter should be very small and this limits the volumetric capacity and hence the power generation capacity of such a turbine. Consequently the practical applications of this turbine would be limited to micro-hydro power generation. The split pipe design of the reaction turbine tested is easy to manufacture and it has been shown to have overall energy conversion efficiency of approximately 50% even under low heads.

13/02259 Studying engine cold start characteristics at low temperatures for CNG and HCNG by investigating low-temperature oxidation

Afkhami, B. *et al. Energy Conversion and Management*, 2012, 64, 122–128.

Engine cold start characteristics at low ambient temperatures based on first firing cycles were studied on a 1.7-litre four-stroke engine for compressed natural gas (CNG) and hydrogen–CNG blend fuels. In these studies engine speed, lambda [(actual air–fuel ratio)/(stoichiometric air–fuel ratio)], intake manifold pressure, injection pulse duration, battery voltage, intake manifold temperature, coolant temperature, and fuel line pressure at natural ambient temperature, 0 °C, and −7.5 °C were measured. Test results indicated for various fuels when ambient temperature decreases, lambda decreases also, but when hydrogen added to CNG (in this investigations the amount of hydrogen was 10% by volume), at similar ambient temperature, lambda increased. This implied that air–fuel mixture became leaner, which in turn could affect unburned hydrocarbons emission. Moreover, when ambient temperature decreases, after-crank-and-fire maximum engine flair speed decreases, but when hydrogen added to CNG, after-crank-and-fire maximum engine flair speed increased in comparison with pure CNG. However, when hydrogen added to CNG some instantaneous rising and falling occurred in engine speed exactly after cranking duration. This research investigated the low-temperature oxidation of CNG and the effect of adding hydrogen at low temperature to find the cause of rising and falling in engine speed. The results indicated consumption of OH by hydrogen during low-temperature oxidation of CNG. The decreased OH concentration leads to retarded heat release and has effect on engine speed.

13/02260 The oxidation of soot particulate in the presence of NO_2

Müller, J.-O. *et al. Catalysis Today*, 2012, 191, (1), 106–111.

The microstructure of soot-like carbons is correlated with their reactivity toward combustion. The focus of this study is on Euro IV heavy duty diesel engine soot. Additionally, two soot samples providing lower and larger particle sizes as their most striking property are taken as references. The effect of NO_2 addition to the O_2-containing gas feed is investigated. It is found that NO_2 accelerates the oxidation of soot in the low-temperature region (250–400 °C) due to an increased surface functionalization with oxygen groups and a subsequent decomposition thereof. Accordingly, initially highly functionalized soot is less susceptible to this effect. The apparent activation energy of combustion is remarkably lowered in the presence of NO_2. It is found that the total reactivity correlates with microstructural features such as surface functionalization, size and curvature of basic structural units, stack height, and particle diameter.

13/02261 Transient operation of internal combustion engines with Rankine waste heat recovery systems

Boretti, A. A. *Applied Thermal Engineering*, 2012, 48, 18–23.

Prior papers have shown the potentials of gasoline-like internal combustion engines fitted with Rankine cycle systems to deliver diesel-like steady state fuel conversion efficiencies recovering the exhaust and the coolant waste heat with off-the-shelf components. In addition to the pros of the technology significantly increasing steady state efficiencies – up to 5% in absolute values and much more in relative values – these papers also mentioned the cons of the technology, increased backpressures, increased weight, more complex packaging, more complex control, troublesome transient operation, and finally the cold start issues that prevent the uptake of the technology. This paper further explores the option to use Rankine cycle systems to improve the fuel economy of vehicles under normal driving conditions. A single Rankine cycle system is integrated here with the engine design. A latest turbocharged 1.6 L direct injection engine has the coolant circuit modified to serve as pre-heater for the Rankine cycle fluid. This fluid is then vaporized and superheated in the boiler/superheater coaxial to the exhaust pipe located downstream of the turbocharger turbine and the closed coupled catalytic converter. The exhaust ports are insulated to reduce the heat losses. The pump of the Rankine cycle system is electrically operated. The expander of the Rankine cycle system drives a generator to recharge the traction battery pack. The thermal engine is connected to the transmission through an electric clutch and a motor/generator that permits to supplement/replace the thermal engine energy supply, recover the braking energy and start/stop the thermal engine. The integrated Rankine cycle system is intended to permit short warming-up profiles, reduced heat losses and reduced weight and packaging issues, delivering significant benefits during cold start driving cycles as the NEDC in addition to the long term, constant load and speed extra urban driving.

Hybrid engine systems

13/02262 Advantages of converting diesel engines to run as dual fuel ethanol–diesel

Boretti, A. *Applied Thermal Engineering*, 2012, 47, 1–9.

The paper considers the option to convert a diesel engine to work as dual fuel with diesel and ethanol following the experience of the diesel heavy duty truck engines conversion to dual fuel diesel and LNG. This opportunity requires the development of dedicated dual fuel injectors for the diesel and the ethanol in small bore applications, or the simple addition of a second ethanol injector in large bore engines. Then, proving a second fuel tank is added, a car or a truck could run with either all diesel or a small diesel and the most part ethanol, typically 5% and 95% in fuel energy. For this latter operation, prior, concurrent or post-injection of the diesel may permit operation diesel-like, mixed gasoline/diesel or mixed gasoline/HCCI of the engine to achieve even better fuel conversion efficiencies than the diesel only over the full range of speeds and loads with all the advantages of the renewable ethanol in terms of environment and energy security.

13/02263 Characteristics of LPG-diesel dual fuelled engine operated with rapeseed methyl ester and gas-to-liquid diesel fuels

Tira, H. S. *et al. Energy*, 2012, 47, (1), 620–629.

A liquefied petroleum gas (LPG)-diesel dual fuelled combustion experimental study was carried out to understand the impact of the properties of the direct injection diesel fuels, such as rapeseed methyl ester (RME) and gas-to-liquid (GTL), on combustion characteristics, engine performance and emissions. The experimental results showed that up to 60% of liquid fuel replacement by LPG was reached while keeping engine combustion variability within the acceptable range and obtaining clear benefits in the soot-NO_x trade-off. However, the amount of LPG was limited by adverse effects in engine thermal efficiency, HC and CO emissions. LPG–RME showed a good alternative to LPG-diesel dual fuelling, as better engine combustion variability, HC, CO and soot behaviour was obtained when compared to the other liquid fuels, mainly due to its fuel oxygen content. On the other hand, NO_x emissions were the highest, but these can be balanced by the application of EGR. LPG–GTL dual fuelling resulted in the highest NO_x emissions benefit over a wide range of engine operating conditions. The high cetane number and the absence of aromatic of GTL are the main parameters for the more favourable soot-NO_x trade-off compared to LPG–ULSD (ultra-low sulfur diesel) dual fuelling.

13/02264 Combustion and emission characteristics of a natural gas-fueled diesel engine with EGR

Abdelaal, M. M. and Hegab, A. H. *Energy Conversion and Management*, 2012, 64, 301–312.

The use of natural gas as a partial supplement for liquid diesel fuel is a very promising solution for reducing pollutant emissions, particularly nitrogen oxides (NO_x) and particulate matters (PM), from conventional diesel engines. In most applications of this technique, natural gas is inducted or injected in the intake manifold to mix uniformly with air, and the homogenous natural gas–air mixture is then introduced to the cylinder as a result of the engine suction. This type of engines, referred to as dual-fuel engines, suffers from lower thermal efficiency and higher carbon monoxide (CO) and unburned hydrocarbon (HC) emissions; particularly at part load. The use of exhaust gas recirculation (EGR) is expected to partially resolve these problems and to provide further reduction in NO_x emission as well. In the present experimental study, a single-cylinder direct injection (DI) diesel engine has been properly modified to run on dual-fuel mode with natural gas as a main fuel and diesel fuel as a pilot, with the ability to employ variable amounts of EGR. Comparative results are given for various operating modes; conventional diesel mode, dual-fuel mode without EGR, and dual-fuel mode with variable amounts of EGR, at different operating conditions; revealing the effect of utilization of EGR on combustion process and exhaust emission characteristics of a pilot ignited natural gas diesel engine.

13/02265 Combustion and emissions characteristics of diesel engine fueled by biodiesel at partial load conditions

An, H. *et al. Applied Energy*, 2012, 99, 363–371.

This paper investigated the performance, combustion and emission characteristics of diesel engine fuelled by biodiesel at partial load conditions. Experiments were conducted on a common-rail fuel injection diesel engine using ultra low sulfur diesel, biodiesel (B100) and their blend fuels of 10%, 20%, 50% (denoted as B10, B20 and B50, respectively) under various loads. The results show that biodiesel/blend fuels have significant impacts on the engine's brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) at partial load conditions. The increase in BSFC for B100 is faster than that of pure diesel with the decrease of engine load. A largest increase of 28.1% in BSFC is found at 10% load. Whereas for BTE, the results show that the use of biodiesel results in a reduced thermal efficiency at lower engine loads and improved thermal efficiency at higher engine loads. Furthermore, the characteristics of carbon monoxide (CO) emissions are also changed at partial load conditions. When running at lower engine loads, the CO emission increases with the increase of biodiesel blend ratio and the decrease of engine speed. However, at higher engine loads, an opposite trend is obtained.

13/02266 Combustion process of JP-8 and fossil Diesel fuel in a heavy duty diesel engine using two-color thermometry

Lee, J. *et al. Fuel*, 2012, 102, 264–273.

An experimental study was performed to analyse the combustion processes of JP-8 and fossil diesel fuel in an optically accessible single-cylinder heavy-duty diesel engine equipped with a high pressure common-rail injection system. In terms of emission, JP-8 emitted less smoke with more HC and NO_x. Direct imaging and two-colour thermometry were applied to verify the emission trend for both fuels. The combustion process was characterized by means of image analysis focusing on the luminosity intensity and its spatial distribution [flame spatial fluctuation (FSF) and flame non-homogeneity (FNH)]. The results from the two-colour thermometry were analysed by the flame temperature and KL factor distribution. From the combustion process analysis of the direct imaging, it was verified that JP-8 had a longer ignition delay compared to fossil diesel fuel regardless of injection pressure. However, flame luminosity of JP-8 was vanished more rapidly. The flame luminosity intensity analysis showed that fossil diesel fuel had stronger flame luminosity overall and duration of visible flame luminosity was longer than JP-8. This implies that fossil diesel fuel had more diffusion dominant combustion. From the flame luminosity variation rate analysis, decreasing rate of flame luminosity for JP-8 was higher compared with fossil diesel fuel, showing that oxidation rate of JP-8 was much higher than fossil diesel fuel. From FSF and FNH analysis, JP-8 showed lower value for both FSF and FNH in the later stage of combustion, because the later stage of combustion with JP-8 has less jet structure in comparison with fossil diesel fuel. The flame temperature field from two-colour thermometry showed that locally high temperature region existed with JP-8. KL factor distribution of JP-8 was distributed more uniformly with a relatively lower level of KL intensity in comparison with fossil diesel fuel in the late stage of combustion.

13/02267 Effect of mixing CO_2 with natural gas–hydrogen blends on combustion in heavy-duty spark ignition engine

Park, P. *et al. Fuel*, 2012, 102, 299–304.

Because further reduction in carbon dioxide (CO_2) will require upgrading the existing engine technology or developing a new type of engine, the addition of hydrogen to natural gas is considered as an alternative that could meet the required emission standards. However, the carbon monoxide/CO_2 generated in the reforming process of natural gas can affect the engine performance and emissions characteristics. The content of CO_2 in the reformed gas can be varied by varying the ingredients or the conditions of the process. Therefore, it is essential to control the air-fuel mixture condition and combustion phasing. In this research, the performance and emission characteristics of an 11 L spark ignition engine using natural gas–hydrogen blends with various CO_2 contents were examined, and an optimization strategy for controlling the excess air ratio and the spark advance timing was assessed. The thermal efficiency decreased with the increased content of CO_2 under a given excess air ratio condition. The increased heat capacity of the mixture reduced the combustion temperature, so that the generation of nitrogen oxides was suppressed. However, total hydrocarbon (THC) emissions and the methane portion of the THC emissions were increased by the introduction of CO_2. The decrease in the exhaust gas temperature also resulted in low conversion efficiency of the oxidation catalyst.

13/02268 Thermodynamic analysis of waste heat recovery for cooling systems in hybrid and electric vehicles

Javani, N. *et al. Energy*, 2012, 46, (1), 109–116.

In this paper, the recovered heat is examined for cabin cooling for ejector and absorption cooling cycles. Energy and exergy analyses are conducted to study the role of various design parameters on the cooling capacity. Waste heat from the battery pack, as well from exhaust gases in the internal combustion engine mode, are the inputs for the boiler and generator. In a city driving mode, waste heat of 15.4 kW will be available. Results show that transferring this waste heat to the boiler in the ejector cooling system leads to a cooling effect of 7.23 kW, with energetic and exergetic coefficients of performance of 0.48 and 0.2 respectively. In the absorption cycle, the energetic COP of the system is 0.53 with a coolant capacity of 7.93 kW. Results also show that, for the electric mode, the cooling capacity is lower than 2 kW, which is insufficient to provide cooling. While recovered heat from hybrid electric vehicles can be used for vehicle cabin cooling by both ejector and absorption systems, the analysis shows that the latter system has a better coefficient of performance and cooling capacity than the ejector system.

Transport battery development

13/02269 Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions

Egbue, O. and Long, S. *Energy Policy*, 2012, 48, 717–729.

Electric vehicles (EVs) are promoted as a viable near-term vehicle technology to reduce dependence on fossil fuels and resulting greenhouse gas (GHG) emissions associated with conventional vehicles (CVs). In spite of the benefits of EVs, several obstacles need to be overcome before EVs will be widely adopted. A major barrier is that consumers tend to resist new technologies that are considered alien or unproved, thus, policy decisions that consider their critical concerns will have a higher level of success. This research identifies potential socio-technical barriers to consumer adoption of EVs and determines if sustainability issues influence consumer decision to purchase an EV. This study provides valuable insights into preferences and perceptions of technology enthusiasts; individuals highly connected to technology development and better equipped to sort out the many differences between EVs and CVs. This group of individuals will likely be early adopters of EVs only if they perceive them to be superior in performance compared to CVs. These results can guide policymakers in crafting energy and transportation policy. It can also provide guidance to EV engineers' decision in incorporating consumer preference into EV engineering design.

13/02270 Battery prices and capacity sensitivity: electric drive vehicles

Juul, N. *Energy*, 2012, 47, (1), 403–410.

The increase in fluctuating power production requires an increase in flexibility in the system as well. Flexibility can be found in generation technologies with fast response times or in storage options. In the transport sector, the proportion of electric drive vehicles is expected to increase over the next decade or two. These vehicles can provide some of the flexibility needed in the power system, in terms of both flexible demand and electricity storage. However, what are the batteries worth to the power system? And does the value depend on battery capacity? This article presents an analysis of the integrated power and transport system, focusing on the sensitivity of the power system configuration according to battery capacity and price of the electric drive vehicle. The value of different battery capacities is estimated, given that the batteries are used for both driving and storage. Likewise, the prices at which the electric drive vehicles become of interest to the power system are found. Smart charge, including the opportunity to discharge (vehicle-to-grid) is used in all scenarios. Analyses show that the marginal benefits decrease the larger the battery. For very high battery prices, large batteries imply that diesel vehicles are preferable to electric drive vehicles.

13/02271 Can a dysprosium shortage threaten green energy technologies?

Hoenderdaal, S. *et al. Energy*, 2013, 49, (1), 344–355.

Dysprosium, one of the various rare earth elements, is currently for more than 99% mined in China. As China is reducing its exports, new mining projects outside of China are needed to sustain supply and meet future demands. Dysprosium is mainly used in permanent magnets to retain the magnet's strength at elevated temperatures. Therefore, the use of dysprosium-doped permanent magnets is preferred in electric vehicles and direct-drive wind turbines. Based on four scenarios it could be shown that dysprosium demand will probably outstrip supply in the short term (up to 2020). Although new mines are being developed, it takes several years for them to become productive. For the long term it is expected that enough dysprosium oxide is available in the earth crust (which is economically feasible to mine with current dysprosium prices) to fulfil the projected demand of dysprosium up to 2050. Recycling of dysprosium can further secure dysprosium supply in the long term by reducing primary dysprosium use by 35% in 2050. Electric vehicles are likely to play a dominant role in future increases in dysprosium demand. Even with the limited market share in 2011, electric vehicles already contribute to 20% of dysprosium use.

13/02272 Can innovative business models overcome resistance to electric vehicles? Better Place and battery electric cars in Denmark

Christensen, T. B. *et al. Energy Policy*, 2012, 48, 498–505.

This paper explores the geographical and policy context for an emergent business model from Better Place to deliver battery electric car mobility in Denmark. It argues that the combination of radically different technologies and a highly complex multi-agency operating environment theoretically provide the conditions and requirements for such an emergent business model. While focused on battery electric cars, renewable energy generation and smart grids, the paper has wider applicability to an understanding of the interplay between place, innovation and sustainability which suggests that diverse solutions are likely to be the characteristic solution rather than ubiquity and standardization. The paper argues, however, that the innovative business model, the deployment of electric vehicles, and the use of renewable energy systems, in this case largely based on wind power, while mutually supportive and contributing to wider policy aims with respect to the reduction of carbon emissions, may still fail in the face of entrenched practices. At the theoretical level it is concluded that theorization of business models needs a broader perspective beyond the typical ‘value creation, value capture’ rubric to better understand the wider role such models have in meeting societal goals, and to understand the structural impediments to organizational and technical innovation.

13/02273 Comparison study on the battery models used for the energy management of batteries in electric vehicles

He, H. *et al. Energy Conversion and Management*, 2012, 64, 113–121.

Battery model plays an important role in the simulation of electric vehicles and states estimation of the batteries in the development of the model-based battery management system. To build a battery model with enough precision and suitable complexity, first this paper summarizes the seven representative battery models, which belong to the simplified electrochemical models or the equivalent circuit models. Then the model equations are built and the model parameters are identified with an online parameter identification method. The battery test bench is built and the experiment schedule is designed. Finally an evaluation is performed on the seven battery models by an experiment approach from the aspects of the estimation accuracy of the terminal voltages. To evaluate the effect of the number of RC networks on the model’s precision, the battery general equivalent circuit models with different RC networks are also discussed further. The results indicate the equivalent circuit model with two RC networks, the *DP* model, has an optimal performance.

13/02274 Electric vehicles as flexible loads – a simulation approach using empirical mobility data

Metz, M. and Doetsch, C. *Energy*, 2012, 48, (1), 369–374.

Due to the rapid increase of wind and photovoltaic generation, flexible storage applications become more important. Electric vehicles are supposed as one option to fill the gap between a fixed energy demand and a stochastic feed in from fluctuating energy sources. But the charging loads will also affect the grid load, since the transport sector contributes considerably to the total energy consumption today. This study examines the conflicting relationship between user mobility and grid support and introduces an approach to simulate large vehicle fleets on the basis of individual driving profiles. A total of 9744 driving profiles from the German mobility panel were used within this examination. 958 were classified as potential early adopters for electric vehicles. Those vehicles could provide grid support in 81% of the time, when charging spots are available at home and at work. The charging loads were simulated under the restrictions of the individual mobility for the scenario 2030. Uncoordinated charging will increase the load fluctuations, whereas coordinated charging loads allow load shifting without limiting the mobility. The additional electricity demand is moderate over the next two decades.

13/02275 Exergy analysis of a TMS (thermal management system) for range-extended EVs (electric vehicles)

Hamut, H. S. *et al. Energy*, 2012, 46, (1), 117–125.

This paper examines a thermal management system (TMS) of a range-extended electric vehicle, which operates on its battery before the gasoline engine engages. In this period of independence of the internal combustion engine, the vehicle performance characteristics such as range, power for acceleration, fuel economy and emissions depend solely on the battery performance. Since the magnitude and uniformity of temperature in battery packs has significant impact on their performance, it is imperative to keep the battery temperature within optimal performance levels through a capable TMS that can efficiently transfer heat within the vehicle. The objective of this paper is to analyse the refrigerant and coolant circuits in the vehicle for cooling during high ambient temperatures and determine the irreversibilities and areas for improvement within these circuits. A second law analysis is used to examine the areas of low exergy efficiency in the system and minimize the entropy generation. Based on the analysis, the energetic coefficient of performance (COP) ranges of 1.8–2.4 and exergetic COP ranges of 0.26–0.39 are calculated for the system. Various parametric studies have been conducted and the most significant impact on the overall exergetic COP is found to be the ambient temperature.

13/02276 On the electrification of road transport – learning rates and price forecasts for hybrid-electric and battery-electric vehicles

Weiss, M. *et al. Energy Policy*, 2012, 48, 374–393.

Hybrid-electric vehicles (HEVs) and battery-electric vehicles (BEVs) are currently more expensive than conventional passenger cars but may become cheaper due to technological learning. Here, this study provides insight into the prospects of future price decline by establishing *ex post* learning rates for HEVs and *ex ante* price forecasts for HEVs and BEVs. Since 1997, HEVs have shown a robust decline in their price and price differential at learning rates of 7 ± 2% and 23 ± 5%, respectively. By 2010, HEVs were only $31 \pm 22\,€_{2010}\,\mathrm{kW}^{-1}$ more expensive than conventional cars. Mass-produced BEVs are currently introduced into the market at prices of $479 \pm 171\,€_{2010}\,\mathrm{kW}^{-1}$, which is $285 \pm 213\,€_{2010}\,\mathrm{kW}^{-1}$ and $316 \pm 209\,€_{2010}\,\mathrm{kW}^{-1}$ more expensive than HEVs and conventional cars. The forecast suggests that price breakeven with these vehicles may only be achieved by 2026 and 2032, when 50 and 80 million BEVs, respectively, would have been produced worldwide. The authors estimate that BEVs may require until then global learning investments of 100–150 billion € which is less than the global subsidies for fossil fuel consumption paid in 2009. These findings suggest that HEVs, including plug-in HEVs, could become the dominant vehicle technology in the next two decades, while BEVs may require long-term policy support.

13/02277 Thermal runaway potential of $LiCoO_2$ and $Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$ batteries determined with adiabatic calorimetry methodology

Jhu, C.-Y. *et al. Applied Energy*, 2012, 100, 127–131.

Thermal runaway hazards related to adiabatic runaway reactions in various 18650 Li-ion batteries were studied in an adiabatic calorimeter with vent sizing package 2 (VSP2). The authors selected two cathode types, $LiCoO_2$ and $Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$, and tested Li-ion batteries to determine the thermal runaway features. The charged 18650 Li-ion batteries were tested to evaluate the thermal hazard characteristics, such as the initial exothermic temperature (T_0), self-heating rate ($\mathrm{d}T/\mathrm{d}t$), pressure rise rate ($\mathrm{d}P/\mathrm{d}t$), pressure–temperature profiles, maximum temperature ($T_{\max}$) and pressure ($P_{\max}$), which are measured by VSP2 with a customized stainless steel test can. The thermal reaction behaviours of the Li-ion battery packs were shown to be an important safety concern for energy storage systems for power supply applications. The thermal abuse trials of the adiabatic calorimetry methodology used to classify the self-reactive ratings of the various cathodes for Li-ion batteries provided the safety design considerations.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

13/02278 A numerical model to evaluate the thermal behaviour of PCM glazing system configurations

Goia, F. *et al. Energy and Buildings*, 2012, 54, 141–153.

The adoption of phase change materials (PCMs) in building components is an up-to-date topic and a relevant number of research activities on this issue is currently on the way. A particular application of PCMs in the building envelope focuses on the integration of such a kind of material into transparent envelope components. A numerical model that describes the thermo-physical behaviour of a PCM layer in combination with other transparent materials (i.e. glass panes) is developed to perform numerical analyses on various PCM glazing systems configurations. The paper illustrates the structure of the model, the main equations implemented and the hypotheses adopted for the model development. The comparison between numerical simulations and experimental data of a simple PCM glazing configuration is also presented to show the potentials and the limitations of the numerical model. While a good agreement between simulations and experimental data can be shown for the surface temperature of the glazing, the comparison between simulated and measured transmitted irradiances and heat fluxes does not always reach the desired accuracy. However, the numerical tool seems to predict well the thermo-physical behaviour of the system and may therefore represent a good starting point for simulations on different configurations of PCM glazing systems.

13/02279 Application of linear free energy relationships to characterizing the sorptive characteristics of organic contaminants on organoclays from water

Zhu, R. *et al. Journal of Hazardous Materials*, 2012, 233–234, 228–234.

Linear free energy relationships (LFERs) were applied to investigate the sorptive characteristics of organic contaminants (OCs) on organoclays from water. Three cetyltrimethylammonium modified montmorillonites (C-Mts) were selected as representative organoclays. The sorption coefficients (log K_{oc}) of OCs on the C-Mts were calculated according to the results of batch sorption experiments. Then the LFER equations for OC sorption on C-Mts from water were developed. The results of this study showed that compared with bulk water, water saturated C-Mts are more polarizable, less polar and cohesive, and have stronger H-bond acceptor capacities and weaker H-bond donor capacities. The primary driving forces for the sorption of OCs from water to C-Mts can be ascribed to the weaker cohesive characteristics of C-Mts as well as the stronger nonspecific Van der Waals interaction between OCs and C-Mts. With increasing cetyltrimethylammonium (CTMA) loading amount, the interaction between OCs and C-Mts increases whereas the C-Mts become more cohesive. Consequently, the sorption capacity of C-Mts first increases with CTMA loading amount and then decreases with further increased loading amount.

13/02280 Assessing cooling energy performance of windows for residential buildings in the Mediterranean zone

Tsikaloudaki, K. *et al. Energy Conversion and Management*, 2012, 64, 335–343.

Heat transfer through windows accounts for a significant proportion of energy used in the building sector for covering both heating and cooling needs, since the optical and the thermal characteristics of conventional fenestration products constitute them more ‘vulnerable’ in energy flows when compared to opaque building elements. In this study, an approach for evaluating the cooling energy performance of residential windows is presented. It is based on a parametric study, which aims at highlighting the impact of the window configuration on its energy behaviour in terms of geometrical characteristics, thermo-physical and optical properties, as well as orientation and shading levels. The results underlined the magnitude of the relationship between the thermal and optical properties of the transparent elements with respect to their orientation; especially for residential buildings, the solar transmittance determines at a considerable extent the cooling energy performance of fenestration, at least in the warmest part of Europe. Furthermore, the statistical analysis of the derived data provided mathematical expressions, which can be used in praxis for predicting the cooling energy performance of windows with respect to their thermal and optical characteristics.

13/02281 Catalytic etherification of glycerol to produce biofuels over novel spherical silica supported Hyflon® catalysts

Frusteri, F. *et al. Bioresource Technology*, 2012, 118, 350–358.

Etherification of glycerol (GLY) with isobutylene (IB) to produce biofuels was investigated in liquid phase using spherical silica supported Hyflon® catalysts (SSHC). As reference catalyst, Amberlyst® 15 (*A-15*) acid ion-exchange resin was used. Experiments were carried out in batch mode at a reaction temperature ranging from 323 to 343 K. SSHC were found to be very effective systems in etherification of glycerol with IB, providing cumulative *di*- and *tri*-ethers yields higher than that obtained by using *A-15* catalyst. Furthermore, such catalysts were stable and easily reusable; no leaching of active phase was observed. The formation of *poly*-substituted ethers, suitable additives for conventional fuels, was favoured by operating at an isobutylene/glycerol molar ratio >3 and low reaction time (<6 h); however, the concentration of *mono*-ether reached values lower than 3 wt% only when SSHC catalyst was used. Turnover frequency of glycerol (TOF_{GLY}) highlighted that SSHC systems were much more active than *A-15* catalyst: the accessibility and nature of active sites and the surface properties of catalysts were indicated as the main factors affecting the catalytic behaviour. A lower acid site density of SSHC than that of *A-15* catalyst was decisive in preventing the occurrence of oligomerization reaction which leads to the formation of *di*-isobutylene (DIB), precursors of gummy products.

13/02282 Experimental study of convective heat transfer from windows with Venetian blinds

Clark, J. *et al. Building and Environment*, 2012, 59, 690–700.

To provide for more detailed and accurate load calculations and energy simulation of buildings, the effect of blinds on convection heat transfer at interior window surfaces was analysed. Based on full-scale experiments in an office-size chamber for various diffuser locations, window geometry, and blind angles, the study provides convective heat transfer models for natural convection, forced convection due to a ceiling slot diffuser, and forced convection due to a floor register. Results are given in the form of correlations which relate either supply volumetric flow rate or room-surface temperature difference to convection heat transfer at both window and exterior wall surfaces. Results show that heat transfer is dependent on supply flow rate, blind angle, diffuser location and window configuration. Results are compared against previously reported data and show that convection in cases with blinds follows the same form as often arises in turbulent forced convection situations, but differs appreciably in magnitude from previously given models for bare windows. These results should allow for more accurate simulation of energy use in buildings and contribute to the construction of more energy efficient buildings.

13/02283 Fabrication and characterization of fully ceramic microencapsulated fuels

Terrani, K. A. *et al. Journal of Nuclear Materials*, 2012, 426, (1–3), 268–276.

The current generation of fully ceramic microencapsulated fuels, consisting of tristructural isotropic fuel particles embedded in a silicon carbide matrix, is fabricated by hot pressing. Matrix powder feedstock is comprised of alumina–yttria additives thoroughly mixed with silicon carbide nanopowder using polyethyleneimine as a dispersing agent. Fuel compacts are fabricated by hot pressing the powder–fuel particle mixture at a temperature of 1800–1900 °C using compaction pressures of 10–20 MPa. Detailed microstructural characterization of the final fuel compacts shows that oxide additives are limited in extent and are distributed uniformly at silicon carbide grain boundaries, at triple joints between silicon carbide grains, and at the fuel particle–matrix interface.

13/02284 Glazing systems with silica aerogel for energy savings in buildings

Buratti, C. and Moretti, E. *Applied Energy*, 2012, 98, 396–403.

Innovative glazing systems with silica aerogel in interspace were investigated for energy saving in buildings. Aerogel is a promising transparent insulating material, due to its low thermal conductivity (down to $0.010\,\mathrm{W\,m^{-1}\,K^{-1}}$), high solar factor, high daylight transmittance and remarkable lightweight. Four samples were constructed with float and low-e glasses and granular or monolithic aerogel in interspace (14 mm thickness). The main optical characteristics of the samples were measured, in order to estimate the light transmittance τ_v, the solar factor g and the colour rendering index R_a, in compliance with EN 410/2011. Finally, the thermal transmittance was calculated. The monolithic aerogel glazings showed the best performance with respect to granular systems, both for light transmittance (0.62 between two 4 mm float glasses) and thermal insulation ($0.6\,\mathrm{W\,m^{-2}\,K^{-1}}$). The solar factor was 0.74. Results showed a very promising behaviour of aerogel windows when compared to the windows normally used in Italy and in European Union countries: monolithic aerogel between two 4 mm float glasses gave a 62% reduction in heat losses, with a 17% reduction in light transmittance when compared to a double glazing with a low-e layer; a high solar factor and colour rendering were also assured.

13/02285 Microwave-assisted preparation of a new esterification catalyst from wasted *flint* kaolin

de Nazaré de Oliveira, A. *et al. Fuel*, 2013, 103, 626–631.

Amazon *flint* kaolin, considered useless from an economic and industrial point of view, was calcined at 850 and 950 °C to obtain metakaolin samples. These samples were subsequently treated with sulfuric acid (4 M) by assisted heating with microwave radiation. The prepared samples were characterized by X-ray diffraction, scanning electron microscopy and N_2 physisorption; the surface acidity was determined by titration with 0.2 M KOH. The materials obtained were used as catalysts in the esterification of oleic acid with methanol. Metakaolin that was calcined at 850 °C and activated at 400 W for 15 min presented a surface area of $187\,\mathrm{m^2\,g^{-1}}$, yielding acidic sites with a concentration of $4.32\,\mathrm{mmol\,g^{-1}}$ and a conversion of 96.5% (115 °C, 40 min, molar ratio of oleic acid:methanol of 1:60). In addition to a lower preparation time, the *flint* metakaolin activated by microwave radiation gave a catalytic performance equivalent or superior to the one prepared by reflux, as well as it showed considerably reduced reaction time and temperature.

13/02286 Novel biomorphic Ni/SiC catalysts that enhance cellulose conversion to hydrogen

Church, T. L. *et al. Catalysis Today*, 2012, 190, (1), 98–106.
High-intensity ultrasonic irradiation was used to improve the synthesis of cellulose-fibre-templated β-SiC by poly(carbomethylsilane) infiltration, and this improved method was also applied to the synthesis of biomorphic SiC materials from jute fibre, bark from a paperbark tree, bamboo fibres, and butterfly wing. The method could also be applied to produce a composite material, containing Ca, Si, C, and O, from poly(carbomethylsilane) and the bone of a cuttlefish. The parent structures were replicated with high fidelity in the final ceramics. Cellulose-fibre- and paperbark-templated β-SiC samples were impregnated with Ni particles, and the resulting material was used as a catalyst for cellulose pyrolysis. The Ni/paperbark-templated β-SiC catalyst was more effective for H_2 generation, likely because paperbark-templated β-SiC had a higher surface area and average pore size than the cellulose-templated β-SiC.

13/02287 Numerical and experimental thermal analysis of an industrial kiln used for frit production

Possamai, T. S. *et al. Applied Thermal Engineering*, 2012, 48, 414–425.
This paper describes a methodology for the study and modelling of the thermal energy in ceramic frit melting kilns with an oxy-fired combustion process through the development of a numerical simulation in computational fluid dynamics (CFD) software. Ceramic frits are vitreous compounds that provide glazes with specific properties for use in the coating of other ceramics, especially those of the ceramic tile industry. The aim of this study is to generate technical subsidies in order to support economically viable proposals for the ceramic industry. The CFD modelling is performed using the commercial software Ansys CFX 11.0, which is based on the method of finite volumes. The geometric domain of resolution consists of the internal cavity of the kiln. The CFD resolution is coupled to a three-dimensional heat conduction code along the kiln walls to determine the external temperature distribution. The thermal problem is composed of the combustion of natural gas with oxygen, the internal turbulent flow of exhaust gases, the energy loss by convection and radiation to the environment through the walls and the radiation within the kiln cavity with participating media. Data collected in an operating kiln are used to verify the numerical solution, achieving a good agreement in the general analysis of the kiln. The numerical solution provides physically consistent results, making it possible to predict the behaviour of the kiln as a whole in similar cases with changes in the parameters of the manufacturing process or in the geometry. Other specific results, such as heat flux inside the kiln, are presented and discussed.

13/02288 Optical diagnostics of collective and non-linear effects in insulators during intense irradiation

Plaksin, O. A. *et al. Journal of Nuclear Materials*, 2012, 426, (1–3), 298.
Optical properties of silica glasses, silica-core fibres, sapphire and alumina under intense irradiation (10^3–10^8 Gy/s) have been measured. It has been shown that the optical methods can be used for investigations of electric charging and phase transitions under irradiation. The radiation-induced non-linear optical effects and the effects of electric charging have been demonstrated. Taking these effects into account is necessary when designing the diagnostic systems of fusion reactors. These effects must be paid attention when conducting optical measurements under irradiation. Until the non-linear optical responses have been examined, there is no reason to give credence to optical diagnostics. Investigations of the radiation-induced non-linear optical properties of optical components are necessary. It has been shown that the optical methods can be used for investigations of the electric charging and phase transitions under irradiation. An optical method of examining the stability of metal phases under irradiation has been proposed. The method is based on *in situ* measurements of optical absorption in the range of the surface-plasmon resonance of metal nanoparticles. Non-equilibrium phase diagrams have been obtained for metal nanoparticles embedded into various optical matrices.

13/02289 Overall energy performance of semi-transparent single-glazed photovoltaic (PV) window for a typical office in Hong Kong

Lu, L. and Law, K. M. *Renewable Energy*, 2013, 49, 250–254.
This paper develops an overall methodology for investigating the thermal and power behaviours of semi-transparent single-glazed photovoltaic window for office buildings in Hong Kong. In order to estimate its overall energy performance, this study is conducted in terms of total heat gain, output power and daylight illuminance. Three simulation models are established, including one-dimensional transient heat transfer model, power generation model and indoor daylight illuminance model. A typical office room reference is chosen as case study, and the weather data from 2003 to 2007 from the Hong Kong Observatory are used as the simulation inputs. By incorporating the simulation results, the overall energy performance can be evaluated in terms of electricity benefits corresponding to five orientations of the studied typical office. The priority of office orientation considering overall energy performance is: south-east, south, east, south-west and west. The findings show that thermal performance is the primary consideration of energy saving in the entire system whereas electricity consumption of artificial lighting is the secondary one. The overall annual electricity benefits are about 900 and 1300 kWh for water-cooled and air-cooled air-conditioning systems, respectively. The application of semi-transparent PV glazed window an not only produces clean energy, but can also reduce building energy use by reducing the cooling load and electrical lighting requirements, which definitely benefits environmental and economic aspects.

13/02290 Summer condition thermal transmittance measurement of fenestration systems using calorimetric hot box

Chen, F. and Wittkopf, S. K. *Energy and Buildings*, 2012, 53, 47–56.
Calorimetric measurement systems are commonly used to determine the thermal transmittance or *U*-value of fenestration specimens, particularly for complex systems with additional external shadings, embedded photovoltaic cells or non-homogeneous patterns. In the past, measurements were mainly performed under winter conditions, where heating of buildings is required, but for tropical climates or summer conditions, where cooling of the building is required, very few thermal transmittance data are available, as most of the calorimetric systems were optimized for the winter conditions only. This paper presents a calorimetric hot box (CHB) for summer conditions complying with international standards, but with advanced measurement methodology and uncertainty analysis model. It includes the measurement results of double glazing units and comparison with simulation results obtained with WINDOW and THERM software. The comparison revealed a difference of less than 5% which can be considered negligible as it falls within the accepted uncertainty. Further results from measurements of complex fenestration systems with semi-transparent thin-film photovoltaics embedded into laminated and double glazing units are also presented. Hence, the presented system and method can pave the way for thermal performance validation of standard and complex fenestration systems necessary for energy efficient buildings in the tropics.

13/02291 The effects of window alternatives on energy efficiency and building economy in high-rise residential buildings in moderate to humid climates

Yaşar, Y. and Kalfa, S. M. *Energy Conversion and Management*, 2012, 64, 170–181.
Currently, focused efforts are being made to determine the influence of windows on the energy consumption and economy of high-rise buildings. Certain window designs and appropriate glazing systems reduce building energy consumption for heating and cooling and contribute to building economy. This paper addresses double-glazed window units that are composed of tinted glass; clear reflective glass; low emissivity (low-e) glass; and smart glass (one surface consists of a high-performance, heat-reflective glass, and other surface has a low-emissivity coated). These materials reduce the heating and cooling loads of buildings by providing solar control and heat conservation. The aim of this study was to investigate the effects of these alternative units, rather than readily available double-glazed units, in two types of flats. The flats have the same construction and operating system, but they have different plan types with regard to building energy consumption and building economy as it relates to life cycle cost analysis. For this study, buildings in Trabzon, in Climate Region II of Turkey, were selected due to its moderate-humid climate. F- and C-type high-rise residential blocks, with flats composed of two to three bedrooms, constructed by the Republic of Turkey's Prime Ministry Housing Development Administration of Turkey are used as models for the simulation. The flat plans in these blocks are modelled using DesignBuilder v.1.8 energy simulation software. The simulation results show that smart-glazed units and those with low emissivity glazing are the most efficient alternatives with regard to building energy consumption and economy.

13/02292 Thermal performance impacts of center-of-glass deflections in installed insulating glazing units

Hart, R. *et al. Energy and Buildings*, 2012, 54, 453–460.
This study examines the thermal performance impact of centre-of-glass (COG) deflections in double- and triple-pane insulating glass units (IGUs) installed at several locations throughout the USA. Deflection was measured during summer and winter temperatures; the results show that outdoor temperature variations can be represented a linear change in COG gap width in double- and triple-pane IGUs within the temperature ranges measured. However, the summer–winter temperature-induced deflection is similar in magnitude to the observed spread in COG deflection of similar units at the same temperature, which suggests that factors other than temperature are of equal importance in

determining the *in situ* deflection of windows. The effect of deflection on thermal performance depends on the IGU's designed gap. Units constructed with smaller-than-optimal gaps often exhibit significant *U*-factor change due to temperature-induced reduction in gap width. This effect is particularly problematic in high-performance triple glazing where small gap dimension changes can have a large impact on performance.

13/02293 Thermal performance of secondary glazing as a retrofit alternative for single-glazed windows

Smith, N. *et al. Energy and Buildings*, 2012, 54, 47–51.

Secondary glazing (or internal storm windows) can be used as a functional alternative to retrofitted insulated glazing units (IGUs) in existing domestic single-glazed window frames. This work investigated the thermal transmittance of four secondary-glazing products – plastic film, magnetically attached plastic sheet, plain and low-E glass. Thermal transmittance measurements were made on a typical New Zealand single-glazed aluminium window, to the method of ASTM C 1199 using a guarded hot box (GHB). Four different secondary-glazing systems were then retrofitted into the window and the thermal transmission measurements determined. All four of the secondary glazing options provided significant thermal improvements to the single-glazed window ($0.15\,m^2\,K/W$), with *R*-values from 0.34 to $0.57\,m^2\,K/W$. Each was also modelled in Window 6 software, with the results found to be within the GHB measurement error. The performance exceeded the expected performance of double glazing retrofitted into the existing framing due to the secondary glazing effectively insulating the framing.

13/02294 Unsteady simulation of energy performance and thermal comfort in non-residential buildings

Buratti, C. *et al. Building and Environment*, 2012, 59, 482–491.

Glazing systems have an important role in buildings. Many studies show that health, comfort and productivity are improved thanks to the contribution of natural light. The aim of the present paper is to evaluate the thermal comfort indexes and the energetic performance of a lecture room in unsteady-state conditions. The research is addressed to non-residential buildings and it consists of two parts: experimental investigation and numerical analysis. Experimental campaigns were carried out in a lecture room of the Faculty of Engineering at the University of Perugia. Several parameters were measured: indoor and outdoor air temperature, solar radiation, surface temperature of external walls, glasses and frames, etc. The thermal comfort indexes (such as predicted mean vote and predicted percentage of dissatisfied) were calculated. The simulations of the thermal behaviour of the tested room were performed using both ENERGYPLUS and TRNSYS software. Simulation models were tested and validated with experimental data; a new weather database was compiled for Perugia, by using the measured hourly data for air temperature, solar radiation and relative humidity. The analysis allowed to compare some different scenarios (glazing types and building orientation) in terms of thermal comfort indexes and energy demand.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

13/02295 A new heterogeneous acid catalyst for esterification: optimization using response surface methodology

Boey, P.-L. *et al. Energy Conversion and Management*, 2013, 65, 392–396.

Studies on heterogeneous acid catalysts for converting free fatty acids into biodiesel have been intensified over the years. This paper focuses on the optimization of a new catalyst system, ferric-alginate as a heterogeneous acid catalyst to esterify lauric acid into methyl laurate. Methanol to lauric acid molar ratio and catalyst amount was optimized using response surface methodology (RSM). The best reaction conditions to achieve methyl laurate yield of 99% was found to be 0.16:1 ferric-alginate to lauric acid mass ratio and 16:1 methanol to lauric acid molar ratio. The reaction time and temperature was fixed at 3 h and methanol refluxing temperature, respectively. The optimized reaction conditions were also used to esterify palm fatty acid distillate to give 89% methyl esters conversion. The acid value of palm fatty acid distillate (PFAD) was reduced from 228 to 0.8 mg KOH/g PFAD.

13/02296 A two-stage bioprocess for hydrogen and methane production from rice straw bioethanol residues

Cheng, H.-H. *et al. Bioresource Technology*, 2012, 113, 23–29.

This study evaluates a two-stage bioprocess for recovering hydrogen and methane while treating organic residues of fermentative bioethanol from rice straw. The obtained results indicate that controlling a proper volumetric loading rate, substrate-to-biomass ratio, or *F*/*M* ratio is important to maximizing biohydrogen production from rice straw bioethanol residues. *Clostridium tyrobutyricum*, the identified major hydrogen-producing bacteria enriched in the hydrogen bioreactor, is likely utilizing lactate and acetate for biohydrogen production. The occurrence of acetogenesis during biohydrogen fermentation may reduce the *B*/*A* ratio and lead to a lower hydrogen production. Organic residues remained in the effluent of hydrogen bioreactor can be effectively converted to methane with a rate of 2.8 mmol CH_4/gVSS/h at VLR of 4.6 kg COD/m^3/d. Finally, approximately 75% of COD in rice straw bioethanol residues can be removed and among that 1.3% and 66.1% of COD can be recovered in the forms of hydrogen and methane, respectively.

13/02297 A weighted average global process model based on two-stage kinetic scheme for biomass combustion

Fang, X. and Yin, L. *Biomass and Bioenergy*, 2013, 48, 43–50.

This research study combustion kinetics of four biomass samples in China, red pine (*Pinus tabulaeformis*), corn straw (hybrid corn Zheng Dan-958), Bermuda grass and bamboo (*Phyllostachys heterocycla* var), using thermogravimetric analysis (TGA). Three stages of combustion process are identified as water evaporation, removal and combustion of volatile matters and combustion of char. Thermal kinetic parameters of each sample are calculated by using first-order Coats–Redfern method based on the TGA data. It is found that the activation energy of the global process is in the range of 53.6–65.2 kJ mol^{-1} with a poor linear correlation. The experimental data are then used to develop a two-stage reaction kinetic scheme with low-temperature region (second stage) and high-temperature region (third stage). The activation energy of the second stage is in the range of 123.5–140.5 kJ mol^{-1}, and that of the third stage was in the range of 59.4–93.4 kJ mol^{-1}, both of which were based on the first-order Coats–Redfern method. Because the global process of actual combustion is different from the TGA, a modified weighted average model is proposed based on the two-stage reaction kinetic scheme. According to the modified model, the kinetic parameters of the global process for actual combustion are calculated and are all found a little smaller than that of the second stages. That will benefit for the combustion simulation and the design of facility of biomass fuel.

13/02298 An optimal U.S. biodiesel fuel subsidy

Wu, H. *et al. Energy Policy*, 2012, 48, 601–610.

Enhanced environmental quality, fuel security, and economic development, along with reduced prices of blended diesel, are often used as justifications for a US federal excise tax exemption on biodiesel fuels. However, the possible effect of increased overall consumption of fuel in response to lower total prices, mitigating the environmental and fuel security benefits, are generally not considered. Taking this price response into account, the optimal US biodiesel subsidy is derived. Estimated values of the optimal subsidy are close to the recently expired subsidy, revealing the subsidy's environmental and security benefits. However, further positive environmental and security benefits from the biodiesel tax-exemption subsidy may be obtained if the subsidy is combined with a federal excise tax on petroleum diesel.

13/02299 Beating back biofuel crop invasions: guidelines on managing the invasive risk of biofuel developments

McCormick, N. and Howard, G. *Renewable Energy*, 2013, 49, 263–266.

The risk of biofuel feedstock species becoming invasive, outcompeting native species and threatening livelihoods is increasing as more advanced crops are planted. However, such risk has so far received limited attention. Biofuel crops are not, by definition, invasive. However, they can become invasive, depending on the area where they are cultivated and how the crop is grown. Some plants do have a higher risk of causing a biological invasion if not managed with this in mind. The most important step is prevention. Extra precautions should be taken to minimize the risk. This paper presents guidelines developed by IUCN on biofuels and invasives for decision-makers and biofuel producers to minimize risks of biological invasions along the biofuels supply chain, from planning, importation, production to transportation and processing. Overall, it is recommended to follow a precautionary approach, comply with relevant regulations and extend assessment and monitoring beyond the field.

13/02300 Biodiesel production by two-stage transesterification with ethanol by washing with neutral water and water saturated with carbon dioxide

Mendow, G. *et al. Bioresource Technology*, 2012, 118, 598–602.

Industrial production of ethyl esters is impeded by difficulties in purifying the product due to high amounts of soap formed during transesterification. A simple biodiesel wash process was developed that allows successful purification of samples containing high amounts of soap. The key step was a first washing with neutral water, which removed the soaps without increasing the acidity or affecting the process yield. Afterward, the biodiesel was washed with water saturated with CO_2, a mild acid that neutralized the remaining soaps and extracted impurities. The acidity, free-glycerine, methanol and soaps concentrations were reduced to very low levels with high efficiency, and using non-corrosive acids. Independently of the initial acidity, it was possible to obtain biodiesel within EN14214 specifications. The process included the recovery of soaps by hydrolysis and esterification, making it possible to obtain the theoretical maximum amount of biodiesel.

13/02301 Biodiesel production using calcium manganese oxide as catalyst and different raw materials

Dias, J. M. *et al. Energy Conversion and Management*, 2013, 65, 647–653.

The use of heterogeneous catalysts for biodiesel production aims to simplify the production process as well as to reduce purification costs and related environmental impacts. Calcium manganese oxide was recently identified by the authors as an interesting heterogeneous catalyst for biodiesel production from animal fat; however, the difference between this and other catalysts, the catalyst activation/deactivation mechanisms, its behaviour in the synthesis using different raw materials as well as the impacts of its use on product quality remained unclear. Therefore, the present work: (i) compared biodiesel production using calcium manganese oxide and other catalysts (CaO and NaOH); (ii) studied the reasons leading to activation/deactivation of the heterogeneous catalyst; (iii) analysed biodiesel heterogeneous synthesis using calcium manganese oxide and different raw materials (lard, waste frying oil and a mixture); and (iv) evaluated raw material and catalyst impact on the product quality. Considering the use of different catalysts, the results showed that, after 8 h of reaction, product purity was similar using the different catalysts, being 92.5 wt% using both NaOH and calcium manganese oxide and 93.8 wt% using CaO. The active species of the heterogeneous catalysts were CaO, in the case of calcinated calcium carbonate, and $Ca_{0.9}Mn_{0.1}O$, in the case of calcinated calcium manganese oxide. Because the deactivating species were different for both catalysts, the calcium manganese oxide required lower activation temperature, which should be an advantage. When using different raw materials, the reaction was slower when lard was used for biodiesel synthesis. Leaching results showed that catalytic behaviour was heterogeneous but further purification of biodiesel might be needed. Using heterogeneous catalysis, after 8 h of reaction, independently of the raw materials used, similar results were obtained regarding the reaction progression; the quality was generally maintained but the water content of the product was improved compared to the homogeneous process.

13/02302 Catalysts derived from waste sources in the production of biodiesel using waste cooking oil

Boey, P.-L. *et al. Catalysis Today*, 2012, 190, (1), 117–121.

Catalysts fully derived from waste materials in order to make sustainable chemical reactions have been a recent topic of interest. Calcined (900 °C, 2 h) calcium oxide (CaO) sourced from waste mud crab shells and cockleshells were mixed in a 1:1 mass ratio to be used for transesterification of waste cooking oil (WCO) at 5 wt% catalyst and a methanol to oil molar ratio of 13:1 for 3 h at methanol refluxing temperature to give 98% conversion. Then, boiler ash (BA) from agricultural waste was used to transesterify WCO at 3 wt% catalyst and a methanol to oil molar ratio of 15:1 for 0.5 h at methanol refluxing temperature to give 89% conversion. In order to reduce the reaction time (for CaO-catalysed reaction) and to increase the conversion (for BA-catalysed reaction) various amounts of BA were added to 5 wt% of mixed CaO and optimized using central composite design (CCD). The optimized conditions predicted by CCD were found to be 3.39 wt% boiler ash, with a reaction time of 32.3 min and a conversion of 99.5%. The predicted results agree with the experimental results (3 wt% boiler ash, reaction time of 30 min with 99% conversion).

13/02303 Catalytic pyrolysis of green algae for hydrocarbon production using H^+ZSM-5 catalyst

Thangalazhy-Gopakumar, S. *et al. Bioresource Technology*, 2012, 118, 150–157.

Microalgae are considered as an intriguing candidate for biofuel production due to their high biomass yield. Studies on bio-oil production through fast pyrolysis and upgrading to hydrocarbon fuels using algal biomass are limited as compared to other terrestrial biomass. Therefore, in this study, a fresh water green alga, *Chlorella vulgaris*, was taken for pyrolysis study. The average activation energy for pyrolysis zone was found to be 109.1 kJ/mol. Fixed-bed pyrolysis of algae gave a bio-oil yield of 52.7 wt%, which accounts for 60.7 wt% carbon yield. In addition, analytical pyrolysis of *C. vulgaris* was carried out in a Py/GC–MS to identify major compounds present in bio-oil with and without catalyst (H^+ZSM-5). The study found that in catalytic pyrolysis, as the catalyst loading increased from zero to nine times of the biomass, the carbon yield of aromatic hydrocarbons increased from 0.9 to 25.8 wt%.

13/02304 Correlation development between the oxidation and thermal stability of biodiesel

Jain, A. and Sharma, M. P. *Fuel*, 2012, 102, 354–358.

Recently, world has been confronted with an energy crisis due to fossil fuel depletion and environmental degradation. Biodiesel is one of the most promising alternative fuels to meet these problems. However the oxidation stability and thermal stability are the problems which are faced im the commercial application of biodiesel. There are standards available discussing the minimum specification of oxidation stability of biodiesel while using in IC engine but at the same time there is no specification is available for thermal stability. Specification for thermal stability can be developed if one can develop the relationship between oxidation and thermal stability. In this study the correlations were developed between the thermal and oxidation stability for different metal contaminated biodiesel. From the correlations it is found that oxidation and thermal stabilities are well correlated. Induction period (IP) decreases with the increase in insoluble formation (Ins) and with the decrease in activation energy (E_a). Error analysis has also been done between the experimental and predicted values of oxidation and thermal stability and found that 95% of the data points are lie between the ±10% error. From the results it can be concluded that the correlations developed can be used for the prediction of Ins and E_a if IP is known or vice versa. Also such correlations can be useful to develop the specification for thermal stability of biodiesel. Combustion is a chemical process by which molecules combine with oxygen and are 'oxidized'. Formation of insolubles and IP are directly related to oxidation reactions, leading to formation of polar compounds and polymers. And therefore an attempt has been made to correlate E_a, Ins and IP in this study.

13/02305 Economic sustainability of a biomass energy project located at a dairy in California, USA

Camarillo, M. K. *et al. Energy Policy*, 2012, 48, 790–798.

Previous experience has demonstrated the tenuous nature of biomass energy projects located at livestock facilities in the USA. In response, the economic sustainability of a 710 kW combined heat and power biomass energy system located on a dairy farm in California was evaluated. This biomass energy facility is unique in that a complete-mix anaerobic digester was used for treatment of manure collected in a flush-water system, co-digestates were used as additional digester feedstocks (whey, waste feed, and plant biomass), and the power plant is operating under strict regulatory requirements for stack gas emissions. Electricity was produced and sold wholesale, and cost savings resulted from the use of waste heat to offset propane demand. The impact of various operational factors was considered in the economic analysis, indicating that the system is economically viable as constructed but could benefit from introduction of additional substrates to increase methane and electricity production, additional utilization of waste heat, sale of digested solids, and possibly pursuing greenhouse gas credits. Use of technology for nitrogen oxide (NO_x) removal had a minimal effect on economic sustainability.

13/02306 Effect of harvest date on combustion related fuel properties of industrial hemp (*Cannabis sativa* L.)

Prade, T. *et al. Fuel*, 2012, 102, 592–604.

Energy crops can increase biomass availability for large-scale biomass-fired heat, power and CHP plants, which can contribute greatly to mitigation of greenhouse gas emissions. Industrial fibre hemp (*Cannabis sativa* L.) is a potential high biomass and energy yielding crop intended for use as solid biofuel, but its fuel properties are insufficiently characterized. Hemp was grown in two independently planned field studies 900 km apart, in southern and northern Sweden. The northern field trials comprised two seasons, two locations and four different cultivars of hemp, while the southern field trial included one hemp variety and one season. Mineral elemental composition (C, H, O, N, S, Cl, Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, Se, Si, Sn, Sr and Zn), heating value, moisture content and initial ash deformation temperature were determined on samples taken between autumn and spring. Spring harvesting significantly improved relevant combustion fuel properties such as moisture content, alkali and ash content and heating value in comparison with autumn harvest. Major fuel properties were not influenced by choice of cultivar or geographical location. Spring-harvested industrial hemp was found to have high initial ash deformation temperatures and a mineral composition similar to that of willow and coniferous wood, indicating that the ash resulting from its combustion will have a low risk of slagging and fouling. Relevant combustion fuel properties were superior to those of other available agricultural biomass feedstocks, such as cereal straw, miscanthus and reed canary grass (straw fuels).

Therefore, hemp is a suitable solid biofuel for large-scale CHP plants and small-scale heating boilers as pellets or briquettes. This study characterized hemp as a solid biofuel, but large-scale combustion tests and an economic analysis are needed to determine the competitiveness of hemp compared with other sources of biomass.

13/02307 Effective catalytic conversion of cellulose into high yields of methyl glucosides over sulfonated carbon based catalyst

Dora, S. *et al. Bioresource Technology*, 2012, 120, 318–321.

An amorphous carbon based catalyst was prepared by sulfonation of the bio-char obtained from fast pyrolysis (N_2 atm; $\approx 550\,^{\circ}C$) of biomass. The sulfonated carbon catalyst contained high acidity of 6.28 mmol/g as determined by temperature programmed desorption of ammonia of sulfonated carbon catalyst and exhibited high catalytic performance for the hydrolysis of cellulose. Amorphous carbon based catalyst containing $-SO_3H$ groups was successfully tested and the complete conversion of cellulose in methanol at moderate temperatures with high yields ca. $\geq 90\%$ of α, β-methyl glucosides in short reaction times was achieved. The methyl glucosides formed in methanol are more stable for further conversion than the products formed in water. The carbon catalyst was demonstrated to be stable for five cycles with slight loss in catalytic activity. The utilization of bio-char as a sulfonated carbon catalyst provides a green and efficient process for cellulose conversion.

13/02308 Effects of blending composition of tung oil and ultrasonic irradiation intensity on the biodiesel production

Manh, D.-V. *et al. Energy*, 2012, 48, (1), 519–524.

The beneficial use of tung oil in pre-blended oil for the production of biodiesel was studied at various blending compositions of tung, canola and palm oils (C_{BT}, C_{BC} and C_{BP}). The effects of C_{BT}, ultrasonic power (P_{WUS}) and sample loading (VL) on the yield (YF) and the properties of acid value, iodine values (IV), kinematic viscosity (KV), density and cold filter plugging point (CFPP) were investigated. The pre-blending of tung oil with palm oil greatly decreases the CFPP of palm oil biodiesel, whereas the presence of canola and palm oils with tung oil reduces the IV and KV of tung oil biodiesel. For $P\mathrm{WUS}VL = 0.92$–2.08 W/mL, C_{BT} can be as high as 60 wt% with 30 wt% C_{BC} and 10 wt% C_{BP} to produce biodiesel with high YF and satisfactory qualities of the said properties.

13/02309 Effects of fermentation substrate conditions on corn–soy co-fermentation for fuel ethanol production

Yao, L. *et al. Bioresource Technology*, 2012, 120, 140–148.

Soy skim, a protein-rich liquid co-product from the aqueous extraction of soybeans, was co-fermented with corn to produce ethanol. Effects of soy skim addition level, type of skim, corn particle size, water-to-solids ratio, and urea on co-fermentation were determined. The addition of 20–100% skim increased the fermentation rate by 18–27% and shortened the fermentation time by 5–7 h without affecting ethanol yield. Finely ground corn or high water-to-solids ratio (≥ 3.0) in the mash gave higher fermentation rates, but did not increase the ethanol yield. When the water was completely replaced with soy skim, the addition of urea became unnecessary. Soy skim retentate that was concentrated by nanofiltration increased fermentation rate by 25%. The highest level of skim addition resulted in a finished beer with 16% solids, 47% protein (dwb) containing 3.6% lysine, and an ethanol yield of 39 g/100 g dry corn.

13/02310 Emergy analysis of oil production from microalgae

da Cruz, R. V. A. and do Nascimento, C. A. O. *Biomass and Bioenergy*, 2012, 47, 418–425.

The use of microalgae and cyanobacteria for the production of biofuels and other raw materials is considered a very promising sustainable technology due to the high areal productivity, potential for CO_2 fixation and use of non-arable land. The production of oil by microalgae in a large-scale plant was studied using emergy analysis. The joint transformity calculated for the base scenario was 1.32E + 5 sej/J, the oil transformity was 3.51E + 5 sej/J, the emergy yield ratio (EYR) was 1.09 and environmental loading ratio was 11.10 and the emergy sustainability index (ESI) was 0.10, highlighting some of the key challenges for the technology such as high energy consumption during harvesting, raw material consumption and high capital and operation costs. Even the best scenario evaluated, namely the one considering the impact of breakthroughs in harvesting and extraction that would enable a process demanding only 50% of the energy (electricity and natural gas) of the base case, still presented a lower efficiency in the utilization of resources than the less competitive alternative biofuels, such as ethanol from corn or grapes. Those results highlight the importance of developing more efficient technologies for harvesting, extraction and drying, with lower capital costs and energy demand, which are also some the areas of the process with highest impact on project economics. The sustainability indices can also be improved by using energy sources with higher renewable emergy content, such as hydroelectricity, wind or biomass.

13/02311 Energy productivity and efficiency of maize accounting for the choice of growing season and environmental factors: an empirical analysis from Bangladesh

Rahman, S. and Rahman, M. S. *Energy*, 2013, 49, (1), 329–336.

The paper evaluates sustainability of maize cultivation in Bangladesh in terms of energy use while taking into account factors affecting choice of the growing season and farmers' production environment using a sample selection framework applied to stochastic frontier models. Results reveal that the probability of growing winter maize is influenced positively by gross return, irrigation, subsistence pressure, soil suitability and temperature variability whereas extension contact influences choice negatively. Significant differences exist between winter and summer maize regarding yield, specific energy, net energy balance, energy use efficiency and technical energy efficiency although both systems are highly sustainable and efficient. The energy output from winter maize is 199,585 MJ/ha which is 53.9% higher than the summer maize output of 129,701 MJ/ha. Also, energy input use of winter maize is 110.6% higher than the summer maize. Energy inputs from mechanical power, seeds, fertilizers and organic manures significantly increase energy productivity of winter maize whereas only mechanical power influences summer maize productivity. However, temperature variation and rainfall significantly reduce energy productivity of summer maize. Policy implications include investments in soil conservation and irrigation, development of weather resistant varieties and raising maize price will boost maize cultivation in Bangladesh, a highly sustainable production technology.

13/02312 Enzymatic hydrolysis of pretreated sugar beet shreds: statistical modeling of the experimental results

Ivetić, D. Ž. *et al. Biomass and Bioenergy*, 2012, 47, 387–394.

In this work sugar beet shreds were subjected to pretreatment and enzymatic hydrolysis in order to convert lignocellulosic material to suitable source for bioethanol production, while response surface methodology and analysis of variance were used to fit the responses and determine significance of the models. Applied acidic extraction of pectic substances as pretreatment procedure gave 65% increase in reducing sugars yield in comparison to that obtained on untreated substrate. A three 3^2 experimental plans were conducted to investigate the influence of polyethylene glycol molecular weight/polyethylene glycol concentration, enzyme concentration/solids load and temperature/polyethylene glycol 4000 on the reducing sugars yield obtained during enzymatic hydrolysis of cellulose in sugar beet shreds. Statistical analysis, based on the results of the Fisher's test and determination coefficients, revealed that proposed quadratic models for experimental plans were significant and had the ability to represent relationship among the independent variables. The highest yield of reducing sugars was obtained at the highest investigated solids load (3% $w\,w^{-1}$) with enzyme dosage 10 FPU g^{-1} substrate and polyethylene glycol 4000 as additive at 1 g $(g\,\text{substrate})^{-1}$, while temperature and hydrolysis time were $47.5\,^{\circ}C$ and 48 h, respectively. This yield of the reducing sugars was 1.6 times higher than the one obtained at lower solids load and temperature and in absence of the polyethylene glycol. Results indicated that by addition of polyethylene glycol 4000 at 1 g $(g\,\text{substrate})^{-1}$, enzyme concentration and hydrolysis time could be reduced by approximately two thirds and one third, respectively, without loss in sugars yield.

13/02313 Fast pyrolysis of coffee grounds: characteristics of product yields and biocrude oil quality

Bok, J. P. *et al. Energy*, 2012, 47, (1), 17–24.

The high demand of renewable energy has been growing nowadays due to shortage of fossil fuels and global warming. The studies on fast pyrolysis of biomass were mostly in progress by using woody biomass, to investigate characteristics of biocrude oil and optimum conditions of fast pyrolysis. Currently a variety of biomass have been used for sample material of fast pyrolysis to produce biocrude oil. In particular, coffee grounds are expected to be a valuable energy source because of consumption growth of coffee and higher heating value than woody biomass. In is study, coffee grounds were chosen as feedstock for fast pyrolysis. The objective of this work was to study the characteristics of product yields and biocrude oil quality depending on reaction temperatures ranging from 673 to 873 K. Also, higher heating value, water content, viscosity, pH, density, ash, and solid residue of the collected biocrude oils were analysed. From the result, the reaction temperature is the most important variable in fast pyrolysis of coffee grounds, significantly influencing the product yields. The highest yield of biocrude oil (54.85%) was obtained at 823 K. Also, the characteristics of biocrude oil were scrutinized by variations of experimental conditions.

13/02314 Hydrothermal pretreatment of microalgae for production of pyrolytic bio-oil with a low nitrogen content

Du, Z. *et al. Bioresource Technology*, 2012, 120, 13–18.

Microalgae can be converted to an energy-dense bio-oil via pyrolysis; however, the relatively high nitrogen content of this bio-oil presents a challenge for its direct use as fuels. Therefore, hydrothermal pretreatment was employed to reduce the N content in *Nannochloropsis oculata* feedstock by removing proteins without requiring significant energy inputs. The effects of reaction conditions on the yield and composition of pretreated algae were investigated by varying the temperature (150–225 °C) and reaction time (10–60 min). Compared with untreated algae, pretreated samples had higher carbon contents and enhanced heating values under all reaction conditions and 6–42% lower N contents at 200–225 °C for 30–60 min. The pyrolytic bio-oil from pretreated algae contained less N-containing compounds than that from untreated samples and the bio-oil contained mainly (44.9% GC–MS peak area) long-chain fatty acids (C14–C18) which can be more readily converted into hydrocarbon fuels in the presence of simple catalysts.

13/02315 H_2 enriched fuels from co-pyrolysis of crude glycerol with biomass

Skoulou, V. K. *et al. Journal of Analytical and Applied Pyrolysis*, 2012, 97, 198–204.

Pyrolysis of glycerol has been identified as a possible route for producing high added value fuels like renewable hydrogen (H_2). Crude glycerol (CG) is the main byproduct of biodiesel industry and without purification it is a low-added value material due to the presence of impurities. Co-pyrolysis of CG with biomass may improve the efficiency of the process and as a primary step of gasification give important information concerning the maximization of H_2 concentration in the produced gas. Moreover, the thermochemical treatment of crude glycerol–biomass mixtures may offer several economic and environmental advantages in biodiesel industry and reduce the cost of biodiesel production. A mixture of CG with olive kernel (OK) was used as pyrolysis feed material. Pyrolysis of a 25 wt% mixture of CG with OK at high temperature ($T = 720$ °C) seemed to promote steam reforming reactions leading to an increase of H_2 concentration of 11.6 vv% in the pyrolysis gas in comparison to H_2 in gas obtained by low temperature pyrolysis ($T = 520$ °C).

13/02316 Influence of light, temperature and metallic ions on biodiesel degradation and corrosiveness to copper and brass

Aquino, I. P. *et al. Fuel*, 2012, 102, 795–807.

Corrosion is a relevant issue regarding the problem of biodiesel compatibility with polymers and metals. This work aims to evaluate the influence of the natural light incidence and temperature in the corrosion rate of brass and copper immersed in commercial biodiesel as well as biodiesel degradation after the contact with metallic ions. The characterization of corrosion behaviour was performed by weight loss measurements according to ASTM G1 and ASTM G31. The experiments according to ASTM G1 were performed at room temperature in light presence and absence. Experiments were also conducted at 55 °C in order to compare with ASTM G31 that is also performed at that temperature. The biodiesel degradation was characterized by water content, oxidation stability, viscosity as well as XRF, IR and Raman spectroscopies. The results of ASTM G1 tests showed that the thickness loss for both metals determined at room temperature is slightly higher when there is light incidence and these values significantly decrease for the highest temperature. The results of ASTM G31 tests indicated that air bubbling along with higher temperature affects mostly immersed samples. Biodiesel in contact with metals shows significant degradation in its properties as evidenced by increasing water content, higher viscosity and lower oxidation stability.

13/02317 Lignocellulosic ethanol: from science to industry

Viikari, L. *et al. Biomass and Bioenergy*, 2012, 46, 13–24.

Lignocellulosic raw materials, not competing with food production, can provide environmental, economic, and strategic benefits for the production of biofuels. The cost of biomass-based biotechnical ethanol production has been recently reduced significantly, mainly due to advances in the conversion techniques; i.e. by improved enzymes and new yeast strains. Conversion of the cellulosic components into fermentable sugars is, however, still the major technological and economical bottleneck in the production of fuels or other high-volume commodity products from cellulosic biomass. Especially, the enzymatic hydrolysis still forms a major cost factor. The targets for reducing the costs of biotechnical conversion processes of lignocelluloses to ethanol can be divided into three categories: the costs of enzymes, the costs of produced sugars and the costs of ethanol production. The efficiencies of individual enzymes can be improved by designing enzymes with optimal domain structures and binding properties, and with higher specific activity, lower end-product inhibition and higher thermal stability, as well as by optimizing the production processes. The cost of the enzymatic hydrolysis is dependent on the efficiency, yield and costs of the pretreatment, synergistic action of cellulases and accessory enzymes, as well as on the needed amount of externally added enzymes. The costs of ethanol production are further affected by the yield, concentration and production rate of ethanol. This work reviews the major bottlenecks in the conversion process, as well as highlights recent approaches to overcome these problems.

13/02318 Management effects on bioenergy sorghum growth, yield and nutrient uptake

Wight, J. P. *et al. Biomass and Bioenergy*, 2012, 46, 593–604.

Bioenergy sorghum (*Sorghum bicolor* L. Moench.) productivity and nutrient uptake may be affected by cropping sequence complexity, fertilization, and residue removal. The goal of this research was to optimize the efficiency of crop management in high biomass (bioenergy) sorghum systems. The two-year field study was conducted in two diverse locations near College Station and Weslaco, Texas. The study utilized a complete factorial design with four replications of the following factors. Rotation: continuous biomass sorghum vs biannual rotation with corn (*Zea mays* L.); stover return: 0, 25, 50% of the sorghum biomass and all corn stover; and N rate: 0 vs non-limiting N. The bioenergy sorghum used was a high-yield photoperiod-sensitive hybrid. Other inputs and practices were those commonly used in the respective areas. Sorghum was harvested for yield, and C, N, P and K, were determined. Rotation, fertilization, and residue return affected yields, plant growth, and nutrient uptake ($p < 0.05$). Total yields, C, N, P, and K uptake in sorghum were significantly increased by rotation and N fertilization both years, while 25% residue return increased sorghum yield and N uptake at College Station the first year. Uptake of C, N, P and K were increased by N fertilization. Sorghum tissue concentrations of N, P and K declined from the first to the second year although mean yield increased, possibly indicating decreased soil nutrient availability after only 2 years. A regression equation was developed relating biomass yield and site, rotation, nitrogen rate, and plant physical traits ($R^2 = 0.67$).

13/02319 Membrane gas permeation in the upgrading of renewable hydrogen from biomass steam gasification gases

Makaruk, A. *et al. Applied Thermal Engineering*, 2012, 43, 134–140.

Combination of the biomass steam gasification and the membrane gas permeation is a potential process for the production of renewable hydrogen. This work first briefly reviews possible membrane materials for the hydrogen enrichment from biomass gasification producer gas mixtures. Subsequently, two permeator arrangements, a single-stage and a two-stage with sweep, are evaluated through numerical modelling. The evaluation discusses the most essential upgrading parameters: achievable hydrogen purity, hydrogen recovery and energy requirement in the upgrading. It is shown that the two-stage arrangement using membranes with H_2/CO_2-selectivity of nine allows production of hydrogen fuel with the hydrogen content of 98% in volume (v/v) and the hydrogen recovery of around 75%. Further improvement of the membrane H_2/CO_2-selectivity is necessary to enhance the process sustainability and economics.

13/02320 Methane yield through anaerobic digestion for various maize varieties in China

Gao, R. *et al. Bioresource Technology*, 2012, 118, 611–614.

The methane potential of nine varieties of fresh maize harvested at three different times and of maize silage was experimentally determined in batch assays. The ultimate methane productivity in terms of volatile solids (VS) was determined as 213.94–313.63, 195.88–334.81 mL/g VS from several fresh and silage maize in three stages, respectively. The average specific methane yield of wax ripeness stage for fresh maize and full ripeness stage for silage maize were higher than that of other stages, respectively. The high-oil varieties of fresh maize and silage varieties of ensiling maize could produce more methane than general varieties in the same ripeness stage. Methane yield of ensiled materials was higher than fresh material. The methane yields of fresh and silage maize in full ripeness stage were ranged 5656–7956 and 4633–8915 m^3/ha, respectively. The corresponding maximum of methane yield came from fresh HO5580 and silage CAU No. 4.

13/02321 Multi-objective optimization of a bio-diesel production process

Sharma, S. and Rangaiah, G. P. *Fuel*, 2013, 103, 269–277.

Bio-diesel is a mixture of fatty acid methyl esters, and is produced by trans-esterification of renewable feed-stock. This study develops an economically attractive and environmentally acceptable bio-diesel production process using multi-objective optimization. It considers bio-diesel production using waste cooking oil as the feed-stock, which can reduce bio-diesel cost. Both the pre-treatment and trans-esterification sections of this process are simulated in a process simulator followed by optimization for multiple objectives using multi-objective differential evolution with taboo list. Profit, fixed capital investment and organic waste from the biodiesel process are considered as objectives for optimization. Effect of variation in feed flow rate on process performance is also studied. The results show that the amount of organic waste can change significantly with only small variations in the economic objectives, and they provide alternative process designs with different environmental impacts, for implementation.

13/02322 Multi-scale modeling of fixed-bed thermo-chemical processes of biomass with the representative particle model: application to pyrolysis

Anca-Couce, A. *et al. Fuel*, 2013, 103, 773–782.

Modelling fixed-bed thermochemical processes of biomass should be considered as a multi-scale problem. The molecular, particle and reactor level should be considered together in the models. A framework for a multi-scale model for dynamic fixed-bed/moving-bed thermo-chemical conversion processes and the respective numerical solution method is introduced: the representative particle model (RPM). In the RPM approach an intra-particle model is solved for each finite volume element of the reactor. All particles within a finite volume element are assumed to obey the same characteristics as the one for which the intra-particle model is solved, which is why it can be considered as representative. The particle level is then considered, as opposed to quasi-continuous models, that are just appropriate when intra-particle gradients of temperatures and concentrations are negligible. And compared to the discrete particle model (DPM), where a model for each particle in the bed (up to 10^5–10^6 particles in technical scale fixed-bed gasification) is solved simultaneously with the fluid-phase balances in the reactor domain, the computational effort is significantly smaller. The RPM is applied to fixed-bed pyrolysis and compared to experimental results available in the literature. The RPM is able to predict the experimental results, describing intra-particle gradients, in a much more feasible time compared to the DPM. The importance of intra-particle gradients in fixed-bed pyrolysis is also highlighted, showing differences in the conversion time of more than 30% when the particle size is doubled, from a particle diameter of 1.24–2.48 cm. Therefore the RPM is a feasible way to include the particle level in a multi-scale description of fixed-bed pyrolysis.

13/02323 Novel zeolite Na-X synthesized from fly ash as a heterogeneous catalyst in biodiesel production

Babajide, O. *et al. Catalysis Today*, 2012, 190, (1), 54–60.

Several studies have been carried out on the production of biodiesel using different heterogeneous catalysts but this study has been able to demonstrate the prospect of utilizing South African class F fly ash as a raw material for zeolite synthesis subsequently applied as a solid base catalyst in the production of biodiesel. A novel faujasite zeolite material synthesized from South African class F fly ash and denoted as FA/Na-X was ion exchanged with potassium to obtain the South African class F fly ash based zeolite FA/K-X. This heterogeneous catalyst was used in the conversion of sunflower oil with methanol to yield fatty acid methyl esters. Different characterization techniques were employed to give more information about this zeolite material. The FA/Na-X and the ion exchanged FA/K-X were applied as catalysts in biodiesel synthesis via transesterification reactions. A high quality biodiesel with a yield of 83.53% was obtained at reaction conditions of methanol:oil ratio of 6:1, catalyst amount of 3% (w/w) of oil and reaction temperature of 65 °C after 8 h.

13/02324 Polymeric ionic liquid (PIL)-supported recyclable catalysts for biomass conversion into HMF

Liu, D. J. and Chen, X.-Y. *Biomass and Bioenergy*, 2013, 48, 181–190.

This contribution reports the first study of recyclable polymeric ionic liquid (PIL)-supported metal (Cr, Al) catalysts for effective biomass (glucose and cellulose) conversion into 5-hydroxymethylfurfural (HMF), a key biorefining building block and biomass platform chemical. Of the five different PILs investigated, poly(3-butyl-1-vinylimidazolium chloride), P[BVIM]Cl, has been found to be most effective; when combined with $CrCl_2$*in situ* or used as the preformed PIL-metalate P[BVIM] $^+[CrCl_3]^-$ in DMF, this PIL-supported catalyst converts glucose to HMF in 65.8% yield at 120 °C for 3 h. This yield is higher than those achieved by the catalysts based on the PIL monomer, [BVIM]Cl–$CrCl_2$, as well as by the most commonly used molecular IL based catalyst, 1-ethyl-3-methylimidazolium chloride ([EMIM]Cl)–$CrCl_2$, under otherwise identical conditions. The P[BVIM]Cl–$CrCl_2$ catalyst system also works well for the cellulose-to-HMF conversion via a two-step process. The analogous PIL–Al catalyst, P[BVIM]Cl–Et_2AlCl, is less effective than the PIL–$CrCl_2$ system, but recyclability tests indicate the PIL–Al system is more recyclable thus achieving a nearly constant HMF yield on six cycles.

13/02325 Prediction of the cetane number of biodiesel using artificial neural networks and multiple linear regression

Piloto-Rodríguez, R. *et al. Energy Conversion and Management*, 2013, 65, 255–261.

Models for estimation of cetane number of biodiesel from their fatty acid methyl ester composition using multiple linear regression and artificial neural networks were obtained in this work. For the obtaining of models to predict the cetane number, an experimental data from literature reports that covers 48 and 15 biodiesels in the modelling-training step and validation step respectively were taken. Twenty-four neural networks using two topologies and different algorithms for the second training step were evaluated. The model obtained using multiple regression was compared with two other models from literature and it was able to predict cetane number with 89% of accuracy, observing one outlier. A model to predict cetane number using artificial neural network was obtained with better accuracy than 92% except one outlier. The best neural network to predict the cetane number was a backpropagation network (11:5:1) using the Levenberg–Marquardt algorithm for the second step of the networks training and showing $R = 0.9544$ for the validation data.

13/02326 Steam gasification of plant biomass using molten carbonate salts

Hathaway, B. J. *et al. Energy*, 2013, 49, (1), 211–217.

This paper explores the use of molten alkali-carbonate salts as a reaction and heat transfer medium for steam gasification of plant biomass with the objectives of enhanced heat transfer, faster kinetics, and increased thermal capacitance compared to gasification in an inert gas. The intended application is a solar process in which concentrated solar radiation is the sole source of heat to drive the endothermic production of synthesis gas. The benefits of gasification in a molten ternary blend of lithium, potassium, and sodium carbonate salts is demonstrated for cellulose, switchgrass, a blend of perennial plants, and corn stover through measurements of reaction rate and product composition in an electrically heated reactor. The feedstocks are gasified with steam at 1200 K in argon and in the molten salt. The use of molten salt increases the total useful syngas production by up to 25%, and increases the reactivity index by as much as 490%. Secondary products, in the form of condensable tar, are reduced by 77%.

13/02327 Synthesis of biodiesel from acidified soybean soapstock using a lignin-derived carbonaceous catalyst

Guo, F. *et al. Applied Energy*, 2012, 98, 47–52.

Biodiesel was produced from acidified soybean soapstocks by using lignin-derived carbonaceous catalyst (LCC). LCC was a solid acidic catalyst prepared by direct sulfonation of residual lignin from *Xanthoceras sorbifolia* Bunge hulls. The textural properties of the catalyst were characterized by ^{13}C MAS NMR, X-ray diffraction, FT-IR, elemental analysis and BET surface area measurement. When 7 wt% of LCC was used in the esterification, the maximum free fatty acids (FFAs) conversion (above 97%) could be achieved at a molar ratio of methanol/oil of 1:9 and a reaction temperature of 70 °C for 5 h. A comparison of catalytic activity between sulfuric acid and LCC revealed that LCC performed 3.5 times higher activity than sulfuric acid with the equivalent active group (SO_3H). Additionally, LCC could be reused at least three times with high FFAs conversion (>80%).

13/02328 Technical and economic assessment for the production of torrefied ligno-cellulosic biomass pellets in the US

Pirraglia, A. *et al. Energy Conversion and Management*, 2013, 66, 153–164.

Manufacturing and trade of wood pellets in the USA has seen an exponential growth in the last few years, triggered by its potential utilization in applications typically dominated by fossil fuels, such as heat, power, and combined cycle generation. This combination holds the promise of delivering a high density, high heat value fuel, making it a better substitute for coal and other fossil fuels. This combined process exists only at pilot-plant levels. Scale-up of the technology and feasibility of such projects remain largely unexplored. This research developed a techno-economic model for the production of torrefied wood pellets, considering critical production parameters, and evaluating sensitivity to changes in capital expenditure (CAPEX), biomass delivered costs, labour, and energy consumption of a facility, evaluated through a case-study. Results indicated that biomass delivered costs and depreciation are the most significant factors influencing production with CAPEX being the most sensitive variable due to high investments in torrefaction reactors. The selection of different torrefaction technologies, and adequate binders, may represent a major improvement in the feasibility of a project by reducing capital costs drastically. Back-calculated price for torrefied wood pellets is $261/tonne (100,000 tonnes/year facility), and delivered price may reach $282/tonne, a similar cost compared to regular pellets. Preliminary analysis of carbon credits as additional income may considerably increase the likeability of the business, and further enhance profitability.

13/02329 The fluidization behaviour of torrefied biomass in a cold model

Rousset, P. *et al. Fuel*, 2012, 102, 256–263.

This experiment proposes a methodology to study the fluidization properties of torrefied biomass. The need for the experiment was highlighted by the impossibility of predicting the behaviour of amorphous, multi-dimensional biomass particles, despite the existence of the kinetic theory of granular flows related to fluidization. The tests were carried out in a cold flow fluidization bed chamber with an internal diameter of 150 mm, with air as the fluidizing medium, and a chamber height of up to 750 mm. Bed-pressure drop was measured as a function of superficial air velocity over a range of bed heights for each individual type of particle. The results showed that the pressure drop was mainly affected by particle size. Interaction between static bed height and temperature did not significantly affect the final results.

13/02330 Thermal decomposition of bio-oil: focus on the products yields under different pyrolysis conditions

Chhiti, Y. *et al. Fuel*, 2012, 102, 274–281.

In this study, pyrolysis process of wood bio-oil was studied. The effects of temperature in the range 550–1000 °C, heating rate in the range 2–2000 °C s^{-1} and ash content of the bio-oil on char, tar and gas yields were investigated. The main gas species generated are quantified by micro-GC: H_2, CO, CO_2, CH_4 and trace amounts of C_2H_4 and C_2H_6. A temperature increase from 550 to 1000 °C enhanced greatly the gas yield, whilst solid and liquid yields decreased significantly. The heating rate was varied in a range covering rapid pyrolysis using the horizontal tubular reactor (HTR) to flash pyrolysis using an entrained flow reactor (EFR). A decrease of char yield from 11 wt% down to 4 wt% was observed when heating rate is changed from 2 to 100 °C s^{-1}. In EFR a flash heating rate of 2000 °C s^{-1} led to a char yield as low as 1 wt%. Bio-oil with a natural ash contents of 0.05 wt% and bio-oil added with 3 wt% of ash were finally pyrolysed. Ash seems to favour re-polymerization reactions that lead to an increase in char yield. A decrease in the amount of gas is observed when ash is added while an increase was a priori expected.

13/02331 Washington biofuel feedstock crop supply under output price and quantity uncertainty

Zheng, Q. *et al. Energy Policy*, 2012, 48, 515–525.

Subsidized development of an in-state biofuels industry has received some political support in the state of Washington, USA. Utilizing in-state feedstock supplies could be an efficient way to stimulate biofuel industries and the local economy. This paper estimates supply under output price and quantity uncertainty for major biofuel feedstock crops in Washington. Farmers are expected to be risk averse and maximize the utility of profit and uncertainty. The study estimates very large Washington price elasticities for corn and sugar beets but a small price elasticity for a third potential feedstock, canola. Even with the large price elasticities for two potential feedstocks, their current and historical production levels in the state are so low that unrealistically large incentives would likely be needed to obtain sufficient feedstock supply for a Washington biofuel industry. Based on this examination of state and regional data, the study found a low likelihood that a Washington biofuels industry will develop in the near future primarily using within-state biofuel feedstock crops.

Geothermal energy

13/02332 A 1 kW_e thermoelectric stack for geothermal power generation – modeling and geometrical optimization

Suter, C. *et al. Applied Energy*, 2012, 99, 379–385.

A thermoelectric stack comprising an array of Bi–Te based thermoelectric converter (TEC) modules is considered for geothermal heat conversion. Each TEC module consists of 127 $(Bi_{0.2}Sb_{0.8})_2Te_3/Bi_2(Te_{0.96}Se_{0.04})_3$ *p*/*n*-type thermoelement pairs, fastened by 30 × 30 mm^2 Al_2O_3 plates. The thermoelement pairs have leg cross-section of 1.05 × 1.05 mm^2, a figure-of-merit equal to 1, and a theoretical heat-to-electricity conversion efficiency of ~5% when the module is operated at a temperature difference of 200 K. A temperature gradient across the thermoelement legs within an array is imposed via a Cu parallel-plate heat exchanger adhering to the Al_2O_3 plates and operating hot and cold water in counter-flow channel configuration. A heat transfer model coupling conduction through the thermoelement legs with convection to and from the Al_2O_3 plates is formulated to investigate the performance of the stack as function of the following parameters: hot water inlet and outlet temperatures (313–413 and 303–393 K, respectively), stack length (300–1500 mm), thermoelement leg length (0.5–4 mm) and hot/cold channel heights (0.2–2 mm). The open-circuit voltages resulting from the temperature differences are within 3% mean relative error of those resulting from temperature differences computed via CFD. The heat transfer model is then applied to optimize a 1 kW_e stack with hot water inlet and outlet temperatures of 413 and 393 K, respectively, for either a maximum heat-to-electricity efficiency of 4.2% or for a minimum volume of 0.0021 m^3.

13/02333 A modified multi-ground-layer model for borehole ground heat exchangers with an inhomogeneous groundwater flow

Lee, C. K. and Lam, H. N. *Energy*, 2012, 47, (1), 378–387.

A modified model for a borehole ground heat exchanger borefield (BHE) of a ground-source heat pump (GSHP) system was developed based on a three-dimensional finite difference scheme which could cater for multiple ground layers and an inhomogeneous groundwater flow in the soil. The model was validated using FLUENT for a single borehole based on a constant load along the effective length of the borehole with good agreement. The present model was then used to investigate the effect of the groundwater table on the performance of the BHE. It was found that with the borehole partially submerged in groundwater flow, the borehole specific load along the borehole depth became stratified, the extent of which depended on the various parameter values. The borehole thermal resistance also varied with the relative groundwater table and the groundwater flow velocity. The trends of the fluid temperature leaving a borehole were quite different between the situations when the borehole was partially submerged in groundwater flow and the case with a full groundwater flow. This meant that the use of an effective groundwater flow velocity to account for the groundwater table effect in a full-groundwater-flow BHE model could be erroneous, particularly for simulation of a large BHE.

13/02334 A new methodology for numerical simulation of geothermal down-hole heat exchangers

Carotenuto, A. *et al. Applied Thermal Engineering*, 2012, 48, 225–236.

This paper presents a numerical procedure for the simulation of heat and fluid flow in a heat exchange system for exploitation of low enthalpy geothermal reservoirs. The authors employ for the first time the generalized model for the mathematical description of heat and fluid flow through saturated porous media in order to study down-hole heat exchanger, well and aquifer, using a single domain approach. Steady state operation of the system is considered and the results obtained are validated against experimental data collected for a geothermal convector prototype installed in an existing geothermal well on the island of Ischia in southern Italy. The comparison shows that the proposed procedure can be successfully used for the simulation of this type of problems, and represents an excellent tool for down-hole heat exchangers optimization. The results of the present model are employed here to analyse the approximate boundary conditions that were previously developed for the simulation of a simplified aquifer model.

13/02335 A novel design approach for small scale low enthalpy binary geothermal power plants

Gabbrielli, R. *et al. Energy Conversion and Management*, 2012, 64, 263–272.

In this paper a novel design approach for small scale low enthalpy binary geothermal power plants is proposed. After the suction, the hot water (brine) superheats an organic fluid (R134a) in a Rankine cycle and, then, is injected back underground. This fact causes the well-known thermal degradation of the geothermal resource during the years. Hence, the binary geothermal power plants have to operate with conditions that largely vary during their life and, consequently, the most part of their functioning is executed in off-design conditions. So, as the novel approach here proposed, the design temperature of the geothermal resource is selected between its highest and lowest values, that correspond to the beginning and the end of the operative life of the geothermal power plant, respectively. Hence, using a detailed off-design performance model, the optimal design point of the geothermal power plant is evaluated maximizing the total actualized cash flow from the incentives for renewable power generation. Under different renewable energy incentive scenarios, the power plant that is designed using the lowest temperature of the geothermal resource always results the best option.

13/02336 Artificial neural network modeling of geothermal district heating system thought exergy analysis

Keçebaş, A. *et al. Energy Conversion and Management*, 2012, 64, 206–212.

This paper deals with an artificial neural network (ANN) modelling to predict the exergy efficiency of geothermal district heating system under a broad range of operating conditions. As a case study, the Afyonkarahisar geothermal district heating system (AGDHS) in Turkey is considered. The average daily actual thermal data acquired from the AGDHS in the 2009–2010 heating season are collected and employed for exergy analysis. An ANN modelling is developed based on backpropagation learning algorithm for predicting the exergy efficiency of the system according to parameters of the system, namely the ambient temperature, flow rate and well head temperature. Then, the recorded and calculated data conducted in the AGDHS at different dates are used for training the network. The results showed that the network yields a maximum correlation coefficient with minimum coefficient of variance and root mean square values. The results confirmed that the ANN modelling can be applied successfully and can provide high accuracy and reliability for predicting the exergy performance of geothermal district heating systems.

13/02337 Artificial neural networks for the generation of geothermal maps of ground temperature at various depths by considering land configuration

Kalogirou, S. A. *et al. Energy*, 2012, 48, (1), 233–240.

In this paper a neural network is used for the generation of geothermal maps (contours) of temperature at three depths (20, 50 and 100 m) in Cyprus. Archived data of temperature recorded at 41 boreholes is used for training a suitable artificial neural network. The complete data were randomly divided into a training and validation dataset. The neural network is used to predict the temperature at any arbitrary location on the island, which can subsequently be used for drawing geothermal maps. For this purpose, a multiple hidden layer feedforward architecture was chosen after testing a number of architectures. The correlation coefficient obtained between the predicted and training dataset is 0.9889, which is very close to 1, indicating an accurate mapping of the data. The validation of the network was performed using the validation (unknown) dataset. The correlation coefficient for the unknown cases was 0.9253. The prediction error for the temperature was confined to less than 1.74 °C, which is considered quite adequate. In order to broaden the database, the patterns used for the validation of the technique were embedded into the training dataset and a new training of the network was performed. The architecture and the other parameters of the network were kept the same as for the validation phase. The correlation coefficient value for this case was equal to 0.9918. A 10×10 km grid is then drawn over a detailed topographic map of Cyprus and the various input parameters were recorded for each grid-point. This information was then supplied to the trained network and by doing so, temperature at the same depths as above was predicted at each grid-point. The x- and y-coordinates and the estimated temperatures at the three depths for both the original boreholes and at the grid-points were then used as input to a specialized contour drawing software in order to draw the geothermal maps. These maps will be a helpful tool for engineers wanting to apply geothermal heat in Cyprus.

13/02338 Case study of heat transfer behavior of helical ground heat exchanger

Park, H. *et al. Energy and Buildings*, 2012, 53, 137–144.

This paper presents an experimental and numerical case study of the heat transfer around the helical ground heat exchanger. With varying helical pitch, indoor thermal response tests (TRTs) were conducted in a dry sand. The tests were analysed based on axisymmetric finite element analyses and recently published heat source models for spiral coil heat exchanger including the modifications of them by adding finite-length line source solution to consider vertical return pipe at centre of helical heat exchanger. In addition to reasonable agreements in soil temperature rises at exteriors the helical heat exchanger, existence of return pipe was found to be important for estimation of heat transfer inside helical exchanger. Besides, the heat source models were found to be applicable to approximate mean fluid temperature during TRTs. The numerical and analytical models were applied to field thermal response test for an energy pile reported in literature. Compared with numerically estimations, the analytical solutions considerably overestimated temperature rise at the exterior of the energy pile. The results reveal that reasonable considerations in estimation of effective thermal properties may be needed when applying the heat source models for energy pile, even though they would evaluate reliable heat transfer behaviour of helical heat exchanger embedded in a homogeneous ground.

13/02339 Comparative efficiency assessment of novel multi-flash integrated geothermal systems for power and hydrogen production

Ratlamwala, T. A. H. and Dincer, D. *Applied Thermal Engineering*, 2012, 48, 359–366.

This paper focuses on a comparative assessment of multi-flash (single to quintuple) geothermal power generating systems integrated with electrolysers through three definitions of energy and exergy efficiencies. The operating parameters such as ambient temperature and geothermal source temperature are varied to investigate their effects on the respective efficiencies of individual and integrated systems. The effect of increasing the number of flashing steps on the efficiencies is also studied. The results show that second and third definitions of efficiency provide with same trends, whereas the first definition provides a completely opposite trend. It is also noticed that a rise in ambient temperature and geothermal source temperature results in higher energy and exergy efficiencies and that the quintuple flash system is found to be the most efficient for practical applications. For a base condition, it is observed that overall system exergy efficiency varies from 6.52% to 47.29% with increase in the number of flash from single flash to quintuple flash.

13/02340 Comparison of thermodynamic cycles for power production from low-temperature geothermal heat sources

Walraven, D. *et al. Energy Conversion and Management*, 2013, 66, 220–233.

The performance of different types of organic Rankine cycles (ORCs) and of the Kalina cycle is investigated and optimized for low-temperature (100–150 °C) geothermal heat sources. A variety of configurations is worth considering. The ORCs can be subcritical or transcritical and can have one or more pressure levels. Each cycle can be a simple one, have recuperation or turbine bleeding and up to 80 different working fluids can be used. Comparison of these cycles to each other and to an optimized Kalina cycle concludes that the transcritical and multi-pressure subcritical cycles are the best ones. Exergetic plant efficiencies of above 50% can be achieved when the brine is allowed to cool down as much as possible. A constraint on the brine outlet temperature causes a strong decrease in the mechanical power output of the cycle. Due to the low heat source temperatures, a low condenser temperature and small temperature differences in the heat exchanger are very important.

13/02341 Defining optimal configurations of geothermal systems using process design and process integration techniques

Gerber, L. and Maréchal, F. *Applied Thermal Engineering*, 2012, 43, 29–41.

This paper presents a systematic methodology for the optimal design of geothermal systems. First, the different components of the system superstructure are separately modelled using flowsheeting software. The superstructure includes the different conversion technologies, the potential resources and the demand profiles in energy services. It covers a wide panel of conventional resources and technologies like deep and shallow aquifers, heat pumps, organic Rankine cycles for combined heat and power production, as well as emerging resources and technologies, like enhanced geothermal systems. Then, resources, technologies and demand profiles models are integrated together using process integration techniques. The configuration of the geothermal system is hence extracted from the superstructure. Finally, the performance of the integrated system is calculated and includes energy and exergy efficiency, investment costs, operating costs and district heating or electricity levelized costs. To account for the seasonal variations of the demand, a multi-period approach is used for the simulation of the superstructure, its integration and the performance calculation. The overall sequence is implemented in a multi-objective optimization framework. The methodology is illustrated by an application case study. The implications of the results are discussed in terms of important effects to be accounted for in the design of geothermal systems.

13/02342 Design of borehole heat exchangers for ground-source heat pumps: a literature review, methodology comparison and analysis on the penalty temperature

Capozza, A. *et al. Energy and Buildings*, 2012, 55, 369–379.

Better energy efficiency of ground coupled heat pump systems in comparison with traditional applications leads to continued growth in the number of installations for space conditioning. The solution with vertical heat exchangers is the most widespread. The design of the borehole heat exchangers (BHEs) is a nodal point, both from an energy efficiency and an economic point of view. In literature, several methods to design these systems are available. However, to promote their application, easy-to-use procedures are required; furthermore designers very often are discouraged from the use of not-open or complicated computational tools. Among the literature models, the ASHRAE method is surely the simplest procedure and, as a consequence, it is suitable for this goal. In this approach, sizing of the BHE length is strongly affected by the parameter named penalty temperature, which is an index to evaluate the long-term behaviour of the borehole field. In this paper, a review of this index is reported and in addition a new approach for its evaluation is presented. Furthermore, a detailed analysis of the proposed method is performed on a real case-study building with only heating conditioning.

13/02343 Energetic, exergetic, economic and environmental evaluations of geothermal district heating systems: an application

Keçebaş, A. *Energy Conversion and Management*, 2013, 65, 546–556.

This study deals with an energetic and exergetic analysis as well as economic and environmental evaluations of Afyon geothermal district heating system (AGDHS) in Afyon, Turkey. In the analysis, actual system data are used to assess the district heating system performance, energy and exergy efficiencies, specific exergy index, exergetic improvement potential and exergy losses. And, for economic and environmental evaluations, actual data are obtained from the Technical Departments. The energy and exergy flow diagrams are clearly drawn to illustrate how much destructions/losses take place in addition to the inputs and outputs. For system performance analysis and improvement, both energy and exergy efficiencies of the overall AGDHS are determined to be 34.86% and 48.78%, respectively. The efficiency improvements in heat and power systems can help achieving energy security in an environmentally acceptable way by reducing the emissions that might otherwise occur. Present application has shown that in Turkey, geothermal energy is much cheaper than the other energy sources, like fossil fuels, and makes a significant contribution towards reducing the emissions of air pollution.

13/02344 Energy extracted from underground rock area by using a horizontal closed loop system in Mutah University/ Jordan

Al-Dabbas, M. A. A. and Al-Rousan, M. A. *Energy Conversion and Management*, 2013, 65, 744–750.

Earth energy systems (EESs) utilize the thermal energy that is stored in rocks and ground water under the earth's surface to provide homes, commercial buildings, and industrial facilities with heating, cooling, and hot water. Solar energy is absorbed by the earth's surface which stores up to 50% of the sun's energy that radiates on it. Consequently, the earth and groundwater's temperature is relatively constant compared to that of the surface air. The earth's temperature is generally warmer than the surface temperature during the colder months of the year, while it is generally cooler than the surface temperature during the hot months of the year. In this study, energy was extracted from the underground rocks at Mutah University in Jordan by using the geothermal horizontal closed loop system. Two-metre holes were drilled into the Earth's surface; copper pipes were inserted for liquid to pass through them into the heat exchange system. Then, the liquid was circulated back into the ground. Several temperature differences were measured and reported in the cold and hot months. The experimental results showed that thermal energy stored in rocks can be used to provide homes with heating, cooling, and hot water with low capital cost and zero environmental emissions.

13/02345 Exergetic performance analysis of Dora II geothermal power plant in Turkey

Ganjehsarabi, H. *et al. Energy*, 2012, 46, (1), 101–108.

An exergy analysis of the Dora II geothermal power plant (DGPP) with 9.5 MW net power output is carried out by using actual plant data to evaluate plant performance and pinpoint the locations of exergy destructions/losses. It aims to determine exergy efficiencies, and exergy destructions in each component of the plant. Exergy destructions in each of the components of the whole plant are determined and illustrated based on the actual data. The exergy destructions/losses take place through losses in the vaporizer, preheater, turbines, pumps and cooling tower, and the re-injection of the geothermal fluid. The exergy destruction ratios for these units and processes accounts for 7.97%, 1.25%, 11.93%, 1.3%, 14.92% and 32.18% of the total exergy input to the plant, respectively. Among the observed components in the plant, the most efficient equipment is found to be the preheater with an exergy efficiency value of 98%. The overall energetic and exergetic efficiencies of the plant are calculated to be 10.7% and 29.6%, respectively. The results show that geothermal energy can make a significant contribution toward reducing the emissions of greenhouse gases.

13/02346 Experimental investigation and optimization of a ground source heat pump system under different indoor set temperatures

Zhai, X. Q. *et al. Applied Thermal Engineering*, 2012, 48, 105–116.

A constant temperature and humidity air-conditioning system driven by a ground source heat pump (GSHP) was designed and constructed in an archives building. The imbalance of earth energy caused by the difference of load between heating mode and cooling mode affects soil temperature, which may result in poor efficiency of the GSHP system. Therefore, the system was optimized based on two aspects. Firstly, the heat recovery technology was used to reheat the air inside the air handling unit (AHU), which aimed at alleviating the imbalance of earth energy. The experimental results showed that the imbalance of earth energy for the system during the whole year was 16.3%, discharging about 33.7% less heat to the soil compared with the system without heat recovery technology. Secondly, the set value of indoor temperature was optimized for the purpose of further reducing the imbalance of earth energy during the system operation. It was shown that the heat transfer between the ground heat exchanger and soil was distinctly affected by the indoor set temperature. Considering the long-term stability of soil temperature and energy conservation of the system, higher value of indoor temperature was suggested to be set on condition that the indoor environment could be met. Both the design method of heat recovery and the optimization of indoor set temperature are meaningful for the suitable utilization of GSHP systems in cooling-dominated buildings.

13/02347 Freezing of geothermal borehole surroundings: a numerical and experimental assessment with applications

Eslami-nejad, P. and Bernier, M. *Applied Energy*, 2012, 98, 333–345.

This study examines the thermal consequences of freezing the ground in the immediate vicinity of geothermal boreholes. First, a one-dimensional radial numerical heat transfer model is developed to evaluate heat transfer from the borehole wall to the ground. The model can account for multiple ground layers in the radial direction and phase change is handled using the effective capacity method. The results obtained from the model are in excellent agreement with the results given by analytical solutions for simple cases. A small-scale experimental set-up has also been built to validate the numerical model using temperature measurements. The apparatus mimics the behaviour of a geothermal borehole and uses a homogeneous saturated laboratory-grade sand to reproduce unsaturated and saturated conditions. It is shown that the results of the numerical model are in good agreement with the experimental results. In the application section, the numerical ground model is combined with a borehole model to examine various scenarios involving typical heat pump operation. Results show that the borehole wall temperature remains around 0 °C for several days when the ground freezes while it would drop to much lower values in non-freezing conditions. Freezing is restricted to a few centimetres around the borehole. If solar energy is available, and a four-pipe borehole with two independent circuits is used, then it is possible to melt the ice and recharge the ground for the next freezing cycle. Using this approach, borehole depth can be reduced by as much as 38% in small thermal conductivity grounds.

13/02348 Optimization of energy extraction for vertical closed-loop geothermal systems considering groundwater flow

Hecht-Méndez, J. *et al. Energy Conversion and Management*, 2013, 66, 1–10.

A combined simulation–optimization procedure is presented to regulate the operation of borehole heat exchangers (BHEs) in a multiple BHE field when groundwater flow exists. Such fields are of increasing interest for large-scale geothermal heating energy supply of buildings, but so far strategic adjustment of energy extraction rates (loads) of the individual BHEs has not been considered in practice. Groundwater flow means an additional advective energy supply, which is advantageous but also complicates proper BHE adjustment. In the presented procedure, the field is simulated by temporally and spatially superimposed moving line source equations. The optimization goal is formulated in an objective function to minimize the thermal impact in the ground, to avoid extreme temperature anomalies, and by this, ultimately improve heat pump performance. For a given seasonal energy demand and total operation time, linear programming efficiently delivers optimized BHE operation patterns. For an examined square lattice of 25 BHEs, the optimized radial load patterns characteristic for conduction dominated conditions change to patterns that are oriented at the groundwater flow when advection dominates. Through this, optimization always levels the temperature distribution in the ground. Also, in comparison to routine practice, mean BHE outlet temperatures can be increased. For the small study case, numerical simulation reveals that already more than 1 K can be achieved, given a seasonal energy demand oriented at common conditions in central Europe. However, for a fixed energy demand, advective heat supply towards the BHEs increases with groundwater flow velocity and thus mitigates the benefits from optimization.

13/02349 Reactive transport modeling of the geothermal system at Bad Blumau, Austria: implications of the combined extraction of heat and CO_2

Alt-Epping, P. *et al. Geothermics*, 2013, 45, 18–30.

Mineral scaling, corrosion and chemical reactions between the re-injected fluid and the aquifer rock affect the long-term exploitation of deep geothermal systems. This study uses numerical models patterned after the geothermal system at Bad Blumau, Austria, to track the passage of the production fluid through the system. As model input the authors use pressure, temperature, and fluid composition data collected at the ground surface, as well as evidence for CO_2 gas exsolution within the production well. From these constraints the authors infer the chemical conditions in the reservoir, assess the geochemical implications of the extraction of heat and $CO_{2(g)}$ at the surface, examine the consequences of fluid re-injection into the reservoir, and identify geochemical indicators of incipient corrosion. Exsolution and the subsequent extraction of $CO_{2(g)}$ from the fluid decreases the total CO_2, increases the pH and, if not suppressed by adding chemical inhibitors, causes precipitation of carbonate minerals. Calculations show that without the inhibition of Ca-bearing carbonates, the production well could be clogged within a few days. The compositional changes caused by CO_2 extraction and the lower temperature of the reinjected fluid trigger disequilibrium reactions at the base of the injection well, potentially affecting the injectivity of the system. Owing to the high redox buffering capacity of the fluid, indicators for incipient corrosion include an increase in the fraction of pyrite in the production well and increase in Fe-oxides/hydroxides near the surface under higher pH and lower temperature conditions.

13/02350 Shallow geothermal energy applied to a solar-assisted air-conditioning system in southern Spain: two-year experience

Rosiek, S. and Batlles, F. J. *Applied Energy*, 2012, 100, 267–276.

This paper describes a shallow geothermal system that was designed as an alternative to the cooling tower in a solar-assisted air-conditioning system installed in southern Spain (Almería). The core idea of this solar-assisted air-conditioning system is to cover the cooling and heating load of the Solar Energy Research Centre (CIESOL), minimizing its environmental impact. In this study, the cooling mode was further investigated. The shallow geothermal system has been operating since May 2010, providing groundwater at 22 °C via a 20-m-deep supply well as a cooling carrier medium. The shallow geothermal system application improves the solar-assisted air-conditioning system's efficiency, thereby reducing its electricity and water consumption. The results demonstrate that during one cooling period, the seasonal shallow geothermal system uses 31% less electrical energy than a cooling tower system. It also achieves savings of $116\,m^3$ in water consumption throughout the summer period.

13/02351 The potential role of data-centres in enabling investment in geothermal energy

Kaniyal, A. A. *et al. Applied Energy*, 2012, 98, 458–466.

A techno-economic analysis is presented, of the potential for data-centres and fibre optic networks to drive investment in geothermal resources. The concept is attractive because of data-centres' stable demand for electricity and refrigeration at a scale of $<5\,MW_e$, corresponding to the output of a single well doublet; because the cost of establishing a fibre optic link is an order of magnitude less than augmenting an electricity transmission network; and because it offers an opportunity for geothermal systems to compete with the retail price of electricity. A comparison of energy delivery outcomes was performed for both engineered geothermal systems (EGS) and hot sedimentary aquifer (HSA) reservoirs to identify the minimum conditions that could make the concept economically attractive. For the high temperature EGS, a single and dual pressure binary organic Rankine cycle (EGS-ORC, EGS-2×ORC), a single stage flash (EGS-flash) and a hybrid flash-binary system (EGS-hybrid) were studied. The HSA system investigated the direct use (HSA-DU) of the geo-fluid in an absorption chiller for refrigeration and the use of coincidental natural gas resources to deliver electricity via an internal combustion engine. The technical performance of these systems was assessed for a range of well-head pressure (EGS only) and geo-fluid flow rate scenarios. The economic performance of the combined set of investments in optical fibre and energy infrastructure was examined by estimating the expected internal rate of return (E[IRR]). The HSA-DU option yielded an E[IRR] of 14%, following the installation of energy capacity equivalent to the output of one well-doublet assuming the displacement of the Australian retail price of electricity; and 12% for the US retail price. In comparison, the EGS-hybrid was found to have an E[IRR] of 8%, if the Australian retail price were displaced and 4% if the US retail price were displaced. The EGS-flash, ORC and 2×ORC scenarios were found to be progressively less attractive than the EGS-hybrid. To identify the conditions under which the concept could satisfy commercial hurdle rates, the sensitivity of the E[IRR] was investigated for the cost of an optical fibre link; the EGS resource depth; the retail price of electricity displaced; and a data-centres' energy consumption profile. Credits for CO_2 emissions abatement at $23/ton were found to have only a marginal influence on the economic performance of the EGS and HSA scenarios examined.

13/02352 Thermodynamic analysis of a binary power cycle for different EGS geofluid temperatures

Zhang, F.-Z. and Jiang, P.-X. *Applied Thermal Engineering*, 2012, 48, 476–485.

Enhanced geothermal systems show promise for meeting growing energy demands. The organic Rankine cycle (ORC) can be used to convert low and medium-temperature geothermal energy to electricity, but the working fluid must be carefully selected for the ORC system design. This paper compares the system performance using R134a, isobutane, R245fa and isopentane for four typical geofluid temperatures below 200 °C. Three type (subcritical, superheated and transcritical) power generation cycles and two heat transfer control models (total heat control model and vaporization control model) are used for different EGS source temperatures and working fluids. The key points concerning ORC working fluid selection for a given resource are: (a) working fluids with critical temperatures near the geofluid source temperature should be considered first, (b) working fluids operating at conditions requiring use of the total heat control model give better efficiencies, (c) the transcritical cycle is good choice with well-developed designs, operating conditions and manufacturing methods. The ORC thermodynamic performance is affected by the turbine expansion characteristics that achieve higher isentropic expansion efficiencies, by environmental and safety aspects, by the heat transfer and flow characteristics and by the economics. An economic performance analysis is also needed to determine which working fluid is the most appropriate.

13/02353 Thermodynamic optimization of ground heat exchangers with single U-tube by entropy generation minimization method

Li, M. and Lai, A. C. K. *Energy Conversion and Management*, 2013, 65, 133–139.

This paper investigates thermodynamic performance of borehole ground heat exchangers with a single U-tube by the entropy generation minimization method which requires information of heat transfer and fluid mechanics, in addition to thermodynamics analysis. This study first derives an expression for dimensionless entropy generation number, a function that consists of five dimensionless variables, including Reynolds number, dimensionless borehole length, scale factor of pressures, and two duty parameters of ground heat exchangers. The derivation combines a heat transfer model and a hydraulics model for borehole ground heat exchangers with the first law and the second law of thermodynamics. Next, the entropy generation number is minimized to produce two analytical expressions for the optimal length and the optimal flow velocity of ground heat exchangers. Then, this paper discusses and analyses implications and applications of these optimization formulas with two case studies. An important finding from the case studies is that widely used empirical velocities of circulating fluid are too large to operate ground-coupled heat pump systems in a thermodynamic optimization way. This paper demonstrates that thermodynamic optimal parameters of ground heat exchangers can probably be determined by using the entropy generation minimization method.

Solar energy

13/02354 A photovoltaic proposed generation promotion policy – the case of Jordan

Abu-Shikhah, N. M. *et al. Energy Policy*, 2012, 49, 154–163.

Jordan has scarce petroleum resources and hence depends to a large extent on imported crude oil, and natural gas to cover its energy needs and to generate electricity in order to cope with the growing demand. The escalating fuel prices associated with the global economic crisis have negative impacts on the economy of Jordan. However, the availability of renewable energy resources (mainly solar, and wind) supported by well-designed and ambitious incentive schemes that run in parallel with an energy efficiency program, can contribute positively in solving the current problems. This may result in a dramatic reduction in energy bill cost in both the short and long term, and also in a better and cleaner environment. In this paper an incentive policy is proposed by the Electricity Regulatory Commission based on supporting the installation of photovoltaic-generating units. ERC plays a major role in this effort which aids decision-makers to adopt the proper policies in the electricity sector. It is anticipated that the implementation of this proposed policy will result in a win–win situation for both consumers and government, and will lead to increasing the energy security level in general, and electricity security in particular, within Jordan.

13/02355 Alternative designs for a 24-h operating solar-powered absorption refrigeration technology

Said, S. A. M. *et al. International Journal of Refrigeration*, 2012, 35, (7), 1967–1977.

The air-conditioning and refrigeration systems in the Kingdom of Saudi Arabia consume more than 60% of the electrical energy of the building sector. Most of the used systems are of the vapour-compression type. Using solar energy to power such systems will save a large amount of energy (primary or electrical) that can be utilized by the production sectors such as industries. Therefore in the present study, alternate designs for a 24-h operating solar-powered absorption refrigeration technology have been developed in detail. The development includes an in-depth review of the design and operation of the conventional and solar-assisted absorption refrigeration systems coming-up with new alternative designs, detailed thermodynamic analysis of some of the new alternative designs and selection of the most suitable alternative design. The analysis indicates that continuously operating solar-powered aqua-ammonia absorption system with refrigerant storage is the most suitable alternative design for an uninterrupted supply of cooling effect.

13/02356 Analysis of a solar assisted heat pump system for indoor swimming pool water and space heating

Chow, T. T. *et al. Applied Energy*, 2012, 100, 309–317.

Solar energy application is a good alternative to replace primary energy source especially for large-scale installations. Heat pumps are also effective means to reduce primary energy consumption. This paper describes a case study with a new design of solar-assisted heat pump (SAHP) for indoor swimming pool space- and water-heating purposes. The system design procedure was first presented. The entire system was then modelled via the TRNSYS simulation environment and the energy performance was evaluated based on the winter time operation schedule. Economic analysis with a range of collector areas was also performed. The simulation results show that the overall system coefficient of performance can reach 4.5, and the fractional factor of energy saving is 79% as compared to the conventional energy system. The economical payback period is less than 5 years.

13/02357 Assessing the solar irradiation potential for solar photovoltaic applications in buildings at low latitudes – making the case for Brazil

Cronemberger, J. *et al. Energy and Buildings*, 2012, 55, 264–272.

In Brazil, a low-latitude country characterized by its high availability and uniformity of solar radiation, the use of PV solar energy integrated in buildings is still incipient. However, at the moment there are several initiatives which give some hints that lead to think that there will be a change shortly. In countries where this technology is already a daily reality, such as Germany, Japan or Spain, the recommendations and basic criteria to avoid losses due to orientation and tilt are widespread. Extrapolating those measures used in high latitudes to all regions, without a previous deeper analysis, is standard practice. They do not always correspond to reality, what frequently leads to false assumptions and may become an obstacle in a country which is taking the first step in this area. In this paper, the solar potential yield for different surfaces in Brazilian cities (located at latitudes between 0° and 30°S) are analysed with the aim of providing the necessary tools to evaluate the suitability of the buildings' envelopes for photovoltaic use.

13/02358 CO_2 splitting by thermo-chemical looping based on $Zr_xCe_{1-x}O_2$ oxygen carriers for synthetic fuel generation

Abanades, S. and Le Gal, A. *Fuel*, 2012, 102, 180–186.

The thermochemical CO_2 splitting via cerium-based mixed oxides is considered. This process targets the recycling and upgrading of CO_2 emissions for the production of solar fuels. The CO_2 reduction is achieved by thermochemical looping using ceria–zirconia solid solutions as oxygen carriers: (1) the mixed oxide is first reduced by thermal activation for releasing some oxygen from its lattice, (2) the reduced oxide is then oxidized with CO_2 for producing carbon monoxide and the initial metal oxide that is recycled to the first step. Reactive cerium-based mixed oxides were first synthesized as nano-powders by different soft chemical routes. Their reactivity was then investigated experimentally by thermogravimetry analysis to demonstrate that the produced nanoparticles react efficiently with CO_2. The two-step process consisting of thermal activation and CO_2-splitting reaction was able to produce CO repeatedly. The influence of the synthesis method, the Zr content in $Zr_xCe_{1-x}O_2$, and the temperature of the CO_2 reduction reaction was investigated. The material was reduced at 1400 °C in flowing Ar and the CO_2 reduction was performed below this temperature (typically in the range of 700–1200 °C). Both the CO production and the material cyclability were improved when decreasing the Zr content, although the reduction extent was lessened. The $Ce_{0.75}Zr_{0.25}O_2$ and $Ce_{0.9}Zr_{0.1}O_2$ redox catalysts withstood repeated cycles without any noticeable sintering and reactivity losses. The most reactive material was the powder synthesized via the Pechini method (242 μmol CO/g at 1000 °C).

13/02359 Deconstructing the dichotomies of solar photovoltaic (PV) dissemination trajectories in Ghana, Kenya and Zimbabwe from the 1960s to 2007

Bawakyillenuo, S. *Energy Policy*, 2012, 49, 410–421.

The profuse dissemination and utilization of solar photovoltaic (PV) technology in the world is indispensable, especially in this era of climate change. However, in the African continent, between 1960 and 2007 Kenya and Zimbabwe were among countries with the highest PV dissemination, while Ghana was among countries with the least disseminations. Analysing empirical data through the lens of the Social Construction of Technology (SCOT) theory, the article aims to uncover the drivers underpinning the disparate dissemination trends of PV in the three countries within the stated period and to tease out lessons apropos replicating the successes within Kenya and Zimbabwe in Ghana. SCOT theory is chosen because it provides an excellent framework for analysing the social shaping of PV's development and diffusion processes in these countries. This theory posits that the shape and meanings of a technology do not reside in it, but are acquired through the heterogeneity of social interactions. Findings in the paper reveal that a gamut of socio-economic and political antecedents informed the varied dissemination outcomes of the technology in these countries. Premised on these findings, the paper recommends critical steps, which Ghana needs to undertake to enhance the replication of the Kenyan and Zimbabwean PV success stories.

13/02360 Development of a continuously operating solar-driven adsorption cooling system: thermodynamic analysis and parametric study

Hassan, H. Z. *et al. Applied Thermal Engineering*, 2012, 48, 332–341.

A novel solar-driven adsorption cooling system that is able to produce cold continuously along the 24-h of the day is proposed in this study. The working principle of the proposed system is based on the constant temperature adsorption cooling cycle which is introduced also in this work. Both of the cooling system principle of operation and the cycle description are explained in details. Moreover, complete thermodynamic analysis is performed for all components of the system as well as processes of the theoretical cycle. Activated carbon-methanol is used as the working pair in the case studied. Furthermore, a parametric study of the influence of many system parameters on the performance is accomplished and discussed as well.

13/02361 Economic performance and policies for grid-connected residential solar photovoltaic systems in Brazil

Mitscher, M. and Rüther, R. *Energy Policy*, 2012, 49, 688–694.

This study analyses the economic competitiveness of grid-connected, distributed solar photovoltaic (PV) generation through small-scale rooftop installations in five Brazilian state capitals. The locations represent a comprehensive set of the two essential parameters for the economic viability of PV–solar irradiation and local electricity tariffs. Levelized electricity costs (LEC) for PV generation and net present values (NPV) for a specific PV system are presented. The analysis comprises three different interest rate scenarios reflecting different conditions for capital acquisition to finance the generators; subsidized, mature market and country-specific risk-adjusted interest. In the NPV analysis, revenue flow is modelled by the sale of PV electricity at current residential tariffs assuming net metering. Using subsidized interest rates, the analysis shows that solar PV electricity is already competitive in Brazil, while in the country-specific risk-adjusted rate, the declining, but still high capital costs of PV make it economically unfeasible. At a mature market interest rate, PV competitiveness is largely dependent on the residential tariff. Economic competitiveness in this scenario is given for locations with high residential tariffs. The authors demonstrate the high potential of distributed generation with photovoltaic installations in Brazil, and show that under certain conditions, grid-connected PV can be economically competitive in a developing country.

13/02362 Efficient scale for photovoltaic systems and Florida's solar rebate program

Burkart, C. S. and Arguea, N. M. *Energy Policy*, 2012, 48, 470–478.

This paper presents a critical view of Florida's photovoltaic (PV) subsidy system and proposes an econometric model of PV system installation and generation costs. Using information on currently installed systems, average installation cost relations for residential and commercial systems are estimated and cost-efficient scales of installation panel wattage are identified. Productive efficiency in annual generating capacity is also examined under flexible panel efficiency assumptions. The authors identify potential gains in efficiency and suggest changes in subsidy system constraints, providing important guidance for the implementation of future incentive programmes. Specifically, it was found that the subsidy system discouraged residential applicants from installing at the cost-efficient scale but over-incentivized commercial applicants, resulting in inefficiently sized installations.

13/02363 Energy efficiency, solar energy conversion and storage in photogalvanic cell

Genwa, K. R. and Sagar, C. P. *Energy Conversion and Management*, 2013, 66, 121–126.

Solar generating photogalvanic cell collect the energy from the sun for conversion to electricity. In the present work photogalvanic effect was studied in photogalvanic cell consisting Tween 60 – Biebrich scarlet – ascorbic acid system. The photopotential, photocurrent and power generated in cell were 919.0 mV, 210.0 μA and 93.15 μW, respectively. The conversion efficiency and storage capacity reported in this article as 0.8967% and 75.0 min. respectively. The effects of other parameters on the cell electrical output were investigated and a cell photoreaction mechanism for the generation of the photocurrent has also been proposed. The results also shown the efficiency along with storage performance of a photogalvanic cell based on Tween 60 – Bibrich scarlet – ascorbic acid system.

13/02364 Experimental investigation of the performance of five types of solar collectors

Sakhrieh, A. and Al-Ghandoor, A. *Energy Conversion and Management*, 2013, 65, 715–720.

Experimental investigation of overall performance, efficiency and reliability of five types of solar collectors is carried out. The systems involved in this study are blue and black coating-selective copper, copper and aluminium collectors in addition to evacuated tubes collectors. The experiments were carried out during April under same conditions for all collectors. The sky was almost clear with an ambient temperature in the range 18–26 °C. Readings are collected daily from 8:00am to 4:00pm. The solar radiation intensity ranged from 154.0 to 1004.33 W/m^2. Considering size of application, cost of appliance, quality and maintenance follow-up, results show that evacuated tube, blue and black coating-selective copper collectors are recommended for medium and large scale applications due to their long life, high-efficiency ease of maintenance. Aluminium collectors are recommended for small applications like houses.

13/02365 Hybrid photovoltaic/diesel green ship operating in standalone and grid-connected mode – experimental investigation

Lee, K.-J. *et al. Energy*, 2013, 49, (1), 475–483.

This paper presents the experimental results from the operation of a prototype green ship in Geoje island, South Korea. As Korea is a peninsula situated between the continent and the sea, its location is ideal for utilizing PV/diesel green ship. It was proposed that the hybrid PV/diesel green ship operates not only in a stand-alone mode but also when connected to a smart grid. To commercialize the proposed green ship in the near future, a conventional passenger ship was fitted with a 3.2 kW photovoltaic (PV) system and operated during the project. The operating strategy of the hybrid PV/diesel system, stability assessment and economic analysis was discussed and the following conclusions were made: (1) the 3.2 kW PV arrays were fixed on the top of the green ship with a tilt of 15°, considering the cost of installation, maintenance cost and stability against wind; (2) the stand-alone mode and grid-connected mode were controlled automatically or manually by the captain of the ship; (3) the hybrid PV/diesel operation was stable with the battery bank during mode changes; (4) the hybrid PV/diesel green ship passed the stability assessment test by the authorized department (KST in this project); (5) the payback period of initial investment can be reduced due to the decreasing PV module costs, increasing diesel fuel costs and CO_2 emission trading system; (6) the hybrid PV/diesel green ship will decrease the dependence on fossil fuels and might be one solution for extending the energy flow from land (smart grid) to island (remote areas); (7) the hybrid PV/diesel green ship is expected to be commercialized and adopted widely to a range of diesel-powered ships. The hybrid PV/diesel green ship has potential use in countries of peninsular or of many islands, especially in upgrading existing stand-alone diesel powered ship under 100 tons due to greenhouse gas regulations.

13/02366 Indoor experimental analysis of glazed hybrid photovoltaic thermal tiles air collector connected in series

Agrawal, S. *et al. Energy and Buildings*, 2012, 53, 145–151.

In this paper, design and experimental analysis of glaze photovoltaic thermal (PVT) tile air collector has been discussed. Fabricated glazed PVT tile consists of a single solar cell, duct and fan for extraction of heat associated with the bottom of solar cell. Observations taken at glazed hybrid PVT tile 1 and tile 2 have been considered as case I and case II, respectively. Experimental validation has also been performed and it has been observed that that there is a good agreement between theoretical and experimental results with correlation coefficient and root mean square percentage deviation of 0.96 and 7.9, respectively. The performance evaluation in terms of electrical efficiency, overall thermal energy and exergy gain of both the cases has been carried out in indoor conditions at various intensities. It has been found that the electrical efficiency is higher in case I as compared to case II. On the contrary the thermal output of case II is higher than case I on same intensity and mass flow rate. It has been found that the average electrical and thermal efficiency of newly designed and fabricated glaze PVT tile is 12.4% and 35.7%, respectively. This economical solar simulator can be used by manufactures for testing of different type of photovoltaic tiles as well as photovoltaic modules.

13/02367 Investigation of solar energy utilization in a novel desiccant based air conditioning system

Hürdoğan, H. *et al. Energy and Buildings*, 2012, 55, 757–764.

In this study, a novel desiccant based air-conditioning system was considered. This system consisted of a desiccant wheel, heat exchangers, fans, evaporative cooler, electric heater unit to simulate solar energy, and refrigeration unit. A model was developed to investigate the utilization of solar energy in the system. In the model, the temperatures obtained from the experiments over the cooling season of 2008 and solar radiation data measured by the State Meteorological Affairs between 1986 and 2006 for Adana were utilized. The increase in the regeneration air temperature due to solar energy assistance for the days, on which the experiments were carried out, was calculated using the model. The results obtained from the model and the experiments were also compared with each other. It may be concluded that utilization of solar energy in the system increases the coefficient of performance between 50% and 120%.

13/02368 Liquid carbon dioxide coating of CdS quantum-dots on mesoporous TiO_2 film for sensitized solar cell applications

Jang, W. *et al. The Journal of Supercritical Fluids*, 2012, 70, 40–47.

CdS quantum dots (QDs) were uniformly deposited on mesoporous TiO_2 films by high-pressure coating with liquid carbon dioxide (l-CO_2) as a coating solvent. The size and coverage of CdS QDs over the TiO_2 surface were controlled by the number of l-CO_2 coating cycles applied at a fixed precursor concentration. The formation of CdS QDs on the mesoporous TiO_2 film was confirmed by scanning electron microscopy (SEM) and high-resolution transmission electron microscopy (HR-TEM). In addition, depth profiling investigation revealed that CdS QDs were uniformly deposited throughout the ~15 μm-thick mesoporous TiO_2 film. The energy conversion efficiency of a CdS QD-sensitized solar cell (QDSSC) was observed to increase up to ~1.33% under standard conditions (1.5 AM, 100 mW cm^{-2}) with an increase in the number of coating cycles to six. Meanwhile, a further increase in the number of coating cycles to ten caused a decrease in the cell performance, which may be attributed to the hindrance of electrolyte infiltration into the mesoporous TiO_2 electrode caused by the blocking of the pores with the coated CdS. The cell performance of the l-CO_2-coated CdS-QDSSC is slightly higher than that of the l-CO_2-coated CdS-QDSSC prepared by a conventional successive ionic layer absorption and reaction (SILAR) method with ethanol as the solvent (1.16%).

13/02369 Optimization of performance characteristics of a mixed dye based photogalvanic cell for efficient solar energy conversion and storage

Yadav, S. and Lal, C. *Energy Conversion and Management*, 2013, 66, 271–276.

Performance characteristics of photogalvanic cells containing mixed dye – brilliant green and celestine blue as photosensitizer with reducing agent EDTA have been experimentally examined. Photopotential of 636 mV and photocurrent of 93 μA are observed for the system. Power conversion efficiency of photogalvanic cell based on brilliant green+ celestine blue–EDTA is estimated as 0.31% while the maximum power output of the cell is found to be 59.1 μW. Photogalvanic cell based on this mixed dye system may be used for 65 min in dark. This study shows that the solar energy conversion capability of a mixture of dyes in aqueous medium is controlled by dye–dye interaction, its photo-degradation and its susceptibility to photo-oxidation.

13/02370 Oscillatory stability analysis with high penetrations of large-scale photovoltaic generation

Shah, R. *et al. Energy Conversion and Management*, 2013, 65, 420–429.

Prompted by the need for clean energy sources, increasing amounts of photovoltaic (PV) generator is connected to the power system around the world, hence, affects many aspects the dynamic and operational characteristics of synchronous generator dominated power system. In this paper, the impact of large-scale PV generation on power system oscillation, especially the inter-area oscillation is studied. The effect of PV on inter-area mode is investigated in New England–New York test system for different level of penetrations and operating conditions. Analysis in the paper reveals that increased PV penetration could affect the critical inter-area mode detrimentally. A trajectory sensitivity based rotor angle norm is evaluated to explore the reason why PV generators are interacting negatively on critical inter-area mode. The primary basis of the method is to convert the PV generator with equivalent sized synchronous generator and evaluate the sensitivity by real power perturbation. The analysis reveals that integration of PV to the system creates higher angular separation among synchronous generators, results inter-area oscillations. A generator ranking based operating point adjustment method is proposed in this paper to minimize the angular separation. The results obtained indicate that the proposed method can effectively minimize the angular separation, hence, enhance the damping of inter-area mode.

13/02371 Overall energy, exergy and carbon credit analysis by different type of hybrid photovoltaic thermal air collectors

Agrawal, S. and Tiwari, G. N. *Energy Conversion and Management*, 2013, 65, 628–636.

In this paper, a comparative analysis of different types of photovoltaic thermal (PVT) air collector namely: (i) unglazed hybrid PVT tiles, (ii) glazed hybrid PVT tiles and (iii) conventional hybrid PVT air collectors has been carried out for the composite climate of Srinagar

(India). The comparative study has been carried out in terms of overall thermal energy and exergy gain, exergy efficiency and carbon credit earned by different type of hybrid PVT air collectors. It has been observed that overall annual thermal energy and exergy gain of unglazed hybrid PVT tiles air collector is higher by 27% and 29.3%, respectively, as compared to glazed hybrid PVT tiles air collector and by 61% and 59.8%, respectively, as compared to conventional hybrid PVT air collector. It has also been observed that overall annual exergy efficiency of unglazed and glazed hybrid PVT tiles air collector is higher by 9.6% and 53.8%, respectively, as compared to conventional hybrid PVT air collector. On the basis of comparative study, it has been concluded that CO_2 emission reduction per annum on the basis of overall thermal energy gain of unglazed and glazed hybrid PVT tiles air collector is higher by 62.3% and 27.7%, respectively, as compared to conventional hybrid PVT air collector and on the basis of overall exergy gain it is 59.7% and 22.7%.

13/02372 Performance analysis and comparison of concentrated evacuated tube heat pipe solar collectors

Nkwetta, D. N. and Smyth, M. *Applied Energy*, 2012, 98, 22–32.

Two profiles of concentrated evacuated tube heat pipe solar collectors made of single-sided and double-sided absorber have been analysed and compared under control conditions and results presented in this paper. These innovative concentrated evacuated tube heat pipe solar collectors were experimentally tested at a tilt angle of 60° to the horizontal. Using in-door solar simulated experimental conditions temperature response, collection efficiency, heat loss coefficients and energy collection rates as well as the incident angle modifier (IAM) were recorded and compared at five different transverse angles (0–40°) at 10° increments. The use of concentrated single-sided and double-sided absorber evacuated tube heat pipe solar collectors is seen to be feasible for integrating solar thermal energy into buildings for heating demands. The concentrated double-sided absorber evacuated tube heat pipe proves better compared to the concentrated single-sided absorber evacuated tube heat pipe solar collector due to higher outlet temperature with greater temperature differential and improved thermal performance. The integration of this innovative system implies that the number of the evacuated tube heat pipe collectors needed to attain higher temperature is reduced. Furthermore, the size of reflectors and related reflector losses are reduced due to the truncated nature of the reflectors providing a low concentration ratio.

13/02373 Photothermal testing before and after degradation of nickel-pigmented aluminium oxide selective absorber prepared by alternate and reverse periodic plating technique

Wazwaz, A. and Al-Salaymeh, A. *Energy Conversion and Management*, 2013, 65, 770–776.

The alternate and reverse periodic plating techniques were used to prepare the selective absorber samples. The glazed type-flat plate collector was used for photothermal testing. The calculated absorptivity of the selective absorbers (before degradation) falls in the range 92.0–97.0% and after degradation falls in the range 88.3–92.2%; while emissivity (before degradation) falls in the range 11.0–22.5% and after degradation falls in the range 11.6–23.4%. The maximum calculated net collective flux (before degradation) is in the range 590–699 W/m^{-2} and after degradation is in the range 566.4–664.1 W/m^{-2}. The conversion efficiency (before degradation) is in the range 0.73–0.78 and after degradation falls in the range 0.70–0.74. Degradation testing carried out in air at different temperatures: 100, 200, 250 and 300 °C. The degradation process leads to a decrease in the solar absorptivity and increase in the thermal emissivity of the films especially at 300 °C. Different parameters are discussed concerning the photothermal and the degradation testing.

13/02374 Photovoltaic-grid connection in the UAE: technical perspective

Al-Sabounchi, A. M. *et al. Renewable Energy*, 2013, 49, 39–43.

Connection of utility-interactive photovoltaic (PV) generators at the distribution level, namely PV distributed generation (PVDG), could bring many benefits to the distribution network. However, deployment of PVDG systems, in any country, requires actual data on the performance of these systems under actual weather conditions. Additionally, it needs compliance with the electrical structure and regulations of the power distribution network in that country. Hence, applying PVDG technology in the United Arab Emirates (UAE) brings forth many considerations and this work aims at tackling potential technical ones. Among these is the role of daily load curve and PV production curve in determining feasible locations and capacities of PVDG systems. The analyses are based on existing case study feeders at the 11 kV level of Abu Dhabi distribution network. Accordingly, the work results in suitable recommendations on feasible locations of PVDG systems. Also it defines rational objectives and constraints for optimal sizing and location of such systems. The other consideration tackled in this work is the performance of PVDG systems in actual UAE weather conditions. Actual data from two pilot PVDG systems installed in Abu Dhabi are collected and analysed. The production of PV array, consistency of voltage and frequency and the conversion efficiency of PV modules and inverters along with the impact of ambient temperature are considered. In the same connection, the influence of accumulated dust deposition on the production of PV array in UAE is also taken over in this work.

13/02375 Renewable energy options for buildings: performance evaluations of integrated photovoltaic systems

Cucchiella, F. *et al. Energy and Buildings*, 2012, 55, 208–217.

Photovoltaic (PV) connected systems are experiencing rapid market growth. This is due to the continually downward trend in PV cost together with government support programs. A scenario has been assumed to analyse the geographical market of PVs. The results provide clear evidence of the influence that some variables have on the profitability of PV investments. This study presents a model for minimizing investment risk and maximizing the return of a renewable energy portfolio in Italy. The value of the paper is in showing that the energy and CO_2 reduction potential that can be reached through consumer-oriented policy measures, but the paper also looks at the effectiveness and social implications of such measures. Private households possess immense unused potential for energy reductions (and climate protection) that could be realized through gains in energy efficiency, behavioural changes, and extended use of low-emission energy. The focus of energy policy has been on businesses rather than on private households, which are only partly captured by direct policy measures. To achieve the goals of climate policies, the current political and scientific discussion increasingly considers measures that aim to reduce energy consumption in the private sector. Quantitative estimates are presented for economic indicators and will show the various effects of policy measures on the implemented household types.

13/02376 Scenarios for solar thermal energy applications in Brazil

Martins, F. R. *et al. Energy Policy*, 2012, 48, 640–649.

The solar and wind energy resource assessment database is used to prepare and discuss scenarios for solar thermal applications in Brazil. The paper discusses low temperature applications (small and large scale water heating) and solar power plants for electricity production (concentrated solar power plants and solar chimney plants) in Brazil. The results demonstrate the feasibility of large-scale application of solar energy for water heating and electricity generation in Brazil. Payback periods for water heating systems are typically below 4 years if they were used to replace residential electric showerheads in low-income families. Large-scale water heating systems also present high feasibility and many commercial companies are adopting this technology to reduce operational costs. The best sites to set up CSP plants are in the Brazilian semi-arid region where the annual energy achieves 2.2 $MW\,h/m^2$ and averages of daily solar irradiation are larger than 5.0 $kW\,h/m^2$/day. The western area of Brazilian Northeastern region meets all technical requirements to exploit solar thermal energy for electricity generation based on solar chimney technology.

13/02377 Short-term prediction of photovoltaic energy generation by intelligent approach

Chow, S. K. H. *et al. Energy and Buildings*, 2012, 55, 660–667.

Population growth and quickly depleting fossil fuel reserves are creating demand for the development and use of renewable energy resources such as solar energy. The evaluation and forecasting of energy demands have become concerns for facility managers, and predicting energy generation plays a critical role in power-system management, scheduling, and dispatch operations. A reliable energy supply forecast can help to prevent unexpected loads and provides key information for decisions made on energy generation and purchase. However, study of energy generation prediction from photovoltaic (PV) systems has been limited over the years, especially concerning short-term predictions. This study adopts the artificial neural network (ANN) to mimic the non-linear correlation between the metrological parameters and energy generated by the PV system. Only dry-bulb temperature, solar elevation angle, solar azimuth angle, and solar radiation are capable of predicting the energy generated by a PV system. The minimum and maximum values of the correlation coefficients for real-time, 10-min, and 20-min predictions are 0.842 and 0.9359, 0.8934 and 0.9862, and 0.8186 and 0.9509, respectively. The confidence intervals under different predictions overlap each other. This can be interpreted to mean that one single set of designated input parameters could predict real-time and up-to-20-min lapse outputs within 95% confidence limits. Facility managers can use this result to help them with the management, scheduling, and dispatching operations in power systems.

13/02378 Solar repowering of Soma-A thermal power plant

ZekiYilmazoğlu, M. *et al. Energy Conversion and Management*, 2012, 64, 232–237.

In this study, solar repowering of the Soma-A thermal power plant in Turkey is investigated using simulations. The Soma A thermal power plant began operation in 1957 and has served until 2010. In the current situation the installed capacity of the power plant is 44 MW_{el} with two units. In the simulations full load and part load operations are considered and compared for three different cases: (1) current case; (2) solar steam generation; and, (3) solar feed water heating. Economic analyses are performed by using the simple payback method. According to the results, solar repowering of Soma A thermal power plant with parabolic trough type collectors can result in 14% power increment at full load operation of the boiler and 14% CO_2 decrement at part load operation of the boiler. However, the economic analysis predicts that the payback time of solar repowering is approximately 10 years for a CO_2 price per ton of US$100 and unit electricity selling price of US$0.24/kW h.

13/02379 The performance and long-term stability of silicon concentrator solar cells immersed in dielectric liquids

Han, X. *et al. Energy Conversion and Management*, 2013, 66, 189–198.

Direct liquid-immersion cooling of concentrator solar cells was proposed as a solution for receiver thermal management of concentrating photovoltaic (CPV) systems. This research investigates the performance and long-term stability of silicon CPV solar cells operated in de-ionized (DI) water, isopropyl alcohol (IPA), dimethyl silicon oil, and ethyl acetate, respectively. Current–voltage characteristics of silicon CPV solar cells are measured. The presence of a thin liquid layer (1.5 mm) results in an increase in the silicon CPV solar cells efficiency by 8.5–15.2% from the reference value. With an increase of the liquid layer thickness above the cell surface up to 9 mm, due to more incident light is absorbed by the thicker liquid layer, the degree of the improvements to the cell efficiency decreases, which also depends to a noticeable degree on the liquid species. Further, more power output from the cells operated in liquids is achieved under higher concentration ratio. The long-term cell performance is discussed through three separate liquid immersion tests. The results from 1.5 mm test demonstrate that degradation of cells performance immersed in IPA and in ethyl acetate mainly occurs by a decrease of J_{sc} and efficiency during 170 days of test. But the long-term organic liquids immersion test (180 days) without silicone sealant involved gives confidence of the reliable performance of the silicon CPV solar cells operated in liquids except for DI water. Therefore, the observed performance decay of the cells in 1.5 mm test is due to the interaction between the silicone sealant and IPA or ethyl acetate. However, long-term immersion results from 9 mm test (100 days) show that the stable electrical performance of the cell is difficult to be achieved when immersed in DI water, which is consistent with the previous report.

13/02380 Thermochemical process for seasonal storage of solar energy: characterization and modeling of a high density reactive bed

Michel, B. *et al. Energy*, 2012, 47, (1), 553–563.

This paper focuses on the characterization and modelling of a solid/gas thermochemical reaction between a porous reactive bed and moist air flowing through it. The aim is the optimization of both energy density and permeability of the reactive bed, in order to realize a high density thermochemical system for seasonal thermal storage for house heating application. Several samples with different implementation parameters (density, binder, diffuser, porous bed texture) have been tested. Promising results have been reached: energy densities about 430–460 kWh m^{-3} and specific powers between 1.93 and 2.88 W/kg of salt. A model based on the assumption of a sharp reaction front moving through the bed during the reaction was developed. It has been validated by a comparison with experimental results for several reactive bed samples and operating conditions.

13/02381 Three-level grid-connected photovoltaic inverter with maximum power point tracking

Tsang, K. M. and Chan, W. L. *Energy Conversion and Management*, 2013, 65, 221–227.

This paper presents a systematic way of designing control scheme for a grid-connected photovoltaic (PV) inverter featuring maximum power point tracking (MPPT) and grid current shaping. Unlike conventional design, only four power switches are required to achieve three output levels and it is not necessary to use any phase-locked-loop circuitry. For the proposed scheme, a simple integral controller has been designed for the tracking of the maximum power point of a PV array based on an improved extremum seeking control method. For the grid-connected inverter, a current loop controller and a voltage loop controller have been designed. The current loop controller is designed to shape the inverter output current while the voltage loop controller can maintain the capacitor voltage at a certain level and provide a reference inverter output current for the PV inverter without affecting the maximum power point of the PV array. Experimental results are included to demonstrate the effectiveness of the tracking and control scheme.

13/02382 Training and certification of PV installers in Europe

Tsoutsos, T. D. *et al. Renewable Energy*, 2013, 49, 222–226.

The high photovoltaic (PV) market growth rates, which are further favoured by the European Union (EU) supporting policies and the national regulatory frameworks, may result to a threat for the PV industry due to the lack of adequately skilled workforce for PV installation and maintenance. This fact may result in poorly installed systems with negative impact on the industry's credibility and development. The PVTRIN, an Intelligent Energy Europe project, addresses to these issues by developing a training and accreditation scheme for technicians/engineers focusing to the installation and maintenance of small-scale PV systems. The training and certification will incorporate the criteria set by the 2009/28/EC Directive regarding requirements for certified training courses and training providers, providing a supporting instrument for EU member states to meet their obligations for acknowledged certifications for RES installers until 31 December 2012. Creating a qualified PV installers workforce, the increased confidence of potential PV owners will lead to market growth.

Wind energy

13/02383 A decision support system for assessing offshore wind energy potential in the North Sea

Schillings, C. *et al. Energy Policy*, 2012, 49, 541–551.

Offshore wind energy (OWE) in the North Sea has the potential to meet large share of Europe's future electricity demand. To deploy offshore wind parks in a rational way, the overall OWE potential has to be realistically determined. This has to be done on an international, cross-border level and by taking into account the existing man-made and nature-related uses of the North Sea. As spatial conflicts will arise between existing uses and the new OWE uses, a decision support system based on a geographic information system was developed. Based on data of existing sea uses and calculation rules for spatial prioritization analysis, the DSS helps in identifying areas that are (1) generally suitable for offshore wind power, (2) strictly excluded or (3) negotiable with respect to other existing sea uses. The combination of this conflict analysis together with cost assumptions for offshore wind farms and their expected electricity yield leads to identification of favourable areas for OWE deployment in the North Sea. This approach helps to reduce the conflict between offshore wind deployment and existing sea uses in the North Sea for future planning. The results can assist decision-makers in developing transnational roadmaps for OWE.

13/02384 A wind turbine evaluation model under a multi-criteria decision making environment

Lee, A. H. I. *et al. Energy Conversion and Management*, 2012, 64, 289–300.

Due to the impacts of fossil and nuclear energy on the security, economics, and environment in the world, the demand of alternative energy resources is expanding consistently and tremendously in recent years. Wind energy production, with its safe and environmental characteristics, has become the fastest growing renewable energy source in the world. The construction of new wind farms and the installation of new wind turbines are important processes in order to provide a long-term energy production. In this research, a comprehensive evaluation model, which incorporates interpretive structural modelling (ISM) and fuzzy analytic network process (FANP), is constructed to select suitable turbines when developing a wind farm. A case study is carried out in Taiwan in evaluating the expected performance of several potential types of wind turbines, and experts in a wind farm are invited to contribute their expertise in determining the importance of the factors of the wind turbine evaluation and in rating the performance of the turbines with respect to each factor. The most suitable turbines for installation can finally be generated after the calculations. The results can be references for decision-makers in selecting the most appropriate wind turbines.

13/02385 An optimization framework for load and power distribution in wind farms

Soleimanzadeh, M. *et al. Journal of Wind Engineering and Industrial Aerodynamics*, 2012, 107–108, 256–262.

The aim of this paper is to develop a controller for wind farms to optimize the load and power distribution. In this regard, the farm controller calculates the power reference signals for individual wind turbine controllers such that the sum of the power references tracks the power demanded by a system operator. Moreover, the reference signals are determined to reduce the load acting on wind turbines at low frequencies. Therefore, a trade-off is made for load and power control, which is formulated as an optimization problem. Afterwards, the optimization problem for the wind farm modelled as a bilinear control system is solved using an approximation method.

13/02386 Analysis of cost estimation and wind energy evaluation using wind energy conversion systems (WECS) for electricity generation in six selected high altitude locations in Nigeria

Ohunakin, S. O. *et al. Energy Policy*, 2012, 48, 594–600.

Two commercial wind turbines namely AN Bonus 300 kW/33 and AN Bonus 1 MW/54 were technically assessed for electricity generation in six selected high altitude sites spreading across the north-west and north-east geopolitical regions of Nigeria by computing their capacity factors, annual power and energy outputs. The economic evaluation of using the two wind energy conversion systems (medium and large) for electric power generation in the selected locations were also estimated using the present value cost method. The results showed that capacity factors of the two turbines in the selected sites ranged between 4.6 and 43%. Average minimum cost per kW h was obtained in Kano as $0.0222/kW h with AN Bonus 1 MW while the highest average cost is $0.2074/kW h with AN Bonus 300 kW in Kaduna. The highest cost in each of the location was obtained with the medium WECs (AN Bonus 300 kW). In addition, Kano and Katsina were also found to be very economical for any of the adopted wind turbine models. Gusau and Kaduna, at cost of unit energy of about $0.30/kW h were found to be more profitable for non-connected electrical and mechanical applications (water pumping, battery charging) than diesel generator.

13/02387 Attitudes, threshold levels and cumulative effects of the daily wind-turbine encounters

Ladenburg, J. and Dahlgaard, J.-O. *Applied Energy*, 2012, 98, 40–46.

An imperative factor in the identification of suitable wind-turbine locations and the subsequent development thereof is the general acceptance of the proposed wind turbines. In this perspective, the existing number of turbines is expected to be a driver of attitude. However, to date only a few studies have assessed the influence of the turbine density in the residential area has on attitude. The present paper sheds light on this issue and finds that attitude towards existing turbines is negatively related with the number of turbines encountered on a daily basis. If the respondents see more than five on-land turbines, they are less positive. However, conditional of seeing more than five turbines a day, opposition does not increase with increasing turbine encounters. These results suggest that the general long-run threshold for opposition towards wind turbines is five turbine encounters per day.

13/02388 Combining choice experiments with psychometric scales to assess the social acceptability of wind energy projects: a latent class approach

Strazzera, E. *et al. Energy Policy*, 2012, 48, 334–347.

A choice experiment exercise is combined with psychometric scales in order: (1) to identify factors that explain support/opposition toward a wind energy development project; and (2) to assess (monetary) trade-offs between attributes of the project. A latent class estimator is fitted to the data, and different utility parameters are estimated, conditional on class allocation. It is found that the probability of class membership depends on specific psychometric variables. Visual impacts on valued sites are an important factor of opposition toward a project, and this effect is magnified when identity values are attached to the specific site, so much that no trade-off would be acceptable for a class of individuals characterized by strong place attachment. Conversely, other classes of individuals are willing to accept compensations, in form of private and/or public benefits. The distribution of benefits in the territory, and preservation of the option value related to the possible development of an archeological site, are important for a class of individuals concerned with the sustainability of the local economy.

13/02389 Control of wind turbines for fatigue loads reduction and contribution to the grid primary frequency regulation

Camblong, H. *et al. Energy*, 2012, 48, (1), 284–291.

The objectives of this work have been to design and analyse a discrete linear quadratic Gaussian (LQG) controller which contributes to the primary frequency control of the grid and to the reduction of the drive-train fatigue loads of a wind turbine (WT). The WT rotational speed and electrical power are controlled using the generator torque and the pitch angle as control variables. The rotational speed and electrical power references are generated in a higher control level depending on the wind speed and a frequency droop. The controller has been designed in Matlab® and has been simulated in Simulink®, in some linear simulation models corresponding to different operating points. These linear models have been obtained from a 5 MW WT model implemented in the commercial wind turbine simulation tool Bladed. The results validate the efficiency of the designed controller, in comparison with another discrete LQG controller which has not been designed to reduce drive-train fatigue loads.

13/02390 Effects of near-wall grid spacing on SST-K-ω model using NREL Phase VI horizontal axis wind turbine

Moshfeghi, M. *et al. Journal of Wind Engineering and Industrial Aerodynamics*, 2012, 107–108, 94–105.

Investigation of the effects of near-wall grid spacing for the SST-K-ω model and study of the aerodynamic behaviour of a horizontal axis wind turbine are the two goals of this paper. The NREL Phase VI is used as the aerodynamic model. Eight different cases are investigated for the near wall grid spacing study. Furthermore, one case is studied in both the SST-K-ω and the Langtry-Menter transitional models. For all cases the total number of nodes are fewer than 5000,000. Thrust forces, flow patterns and pressure coefficients are compared at different wind speeds. The thrust values of the SST-K-ω are not in a good agreement with the test results. The streamlines show that the inboard section of the blade has a severe complex three-dimensional flow which separates at low velocities; the mid-span section stays attached for higher velocities and the outboard part has two-dimensional-like behaviour and separates as the last part. Also, for areas with complex separation, reattachment and sever spanwise flow (e.g. at the inboard section), the SST-K-ω mispredicts the pressure values. Generally, the SST-K-ω over predicts the separation by mispredicting the separation point. Besides, it is observed that Gamma–Theta transitional model behaves differently from the SST-K-ω, especially at the inner part and the results are closer to the test results.

13/02391 Efficiency analysis and controller design of a continuous variable planetary transmission for a CAES wind energy system

Shaw, D. *et al. Applied Energy*, 2012, 100, 118–126.

This study proposes a compressed air storage system (CAES) wind energy storage system composed of a windmill, a continuous variable planetary transmission, a flywheel, a clutch, a reciprocating compressor, and an air tank. The mode of transformation of wind energy into compressed air in the system is also illustrated, in addition to details on the process of the controller design. The system controller can adjust the gear ratio according to the wind speed (V_{wind}) and rotational speed of the flywheel ($\omega_{flywheel}$). With a proper controller design to control the gear ratio, the flywheel can rapidly reach a rotational speed that is suitable for compressing the air into a tank. In addition, the windmill can be operated at the most efficient point. Therefore, transformation efficiency of wind energy into compressed air could be improved. After completion of the controller design, the efficiency of the two air compression systems (one system is driven directly by the windmill and another is driven by the flywheel) are compared to determining the target for improving performance in the future.

13/02392 Evaluation of offshore wind resources by scale of development

Möller, M. *et al. Energy*, 2012, 48, (1), 314–322.

Offshore wind energy has developed rapidly in terms of turbine and project size, and currently undergoes a significant up-scaling to turbines and parks at greater distance to shore and deeper waters. Expectations to the positive effect of economies of scale on power production costs, however, have not materialized as yet. On the contrary, anticipated electricity generation costs have been on the increase for each increment of technology scale. Moreover, the cost reductions anticipated for progressing along a technological learning curve have are not apparent, and it seems that not all the additional costs can be explained by deeper water, higher distance to shore, bottlenecks in supply or higher raw material costs. The present paper addresses the scale of offshore wind parks for Denmark and invites to reconsider the technological and institutional choices made. Based on a continuous resource-economic model operating in a geographical information systems environment, which describes resources, costs and area constraints in a spatially explicit way, the relation between project size, location, costs and ownership is analysed. Two scenarios are presented, which describe a state-of-the-art development as well as a sketch of smaller, locally owned parks that may have several economic advantages but require a greater planning and acceptance because of higher visual impact and area competition.

13/02393 Integrating wind power using intelligent electric water heating

Fitzgerald, N. *et al. Energy*, 2012, 48, (1), 135–143.

Dwindling fossil fuel resources and pressures to reduce greenhouse gas emissions will result in a more diverse range of generation portfolios for future electricity systems. Irrespective of the portfolio mix the overarching requirement for all electricity suppliers and system operators is to instantaneously meet demand, to operate to standards and reduce greenhouse gas emissions. Therefore all electricity market participants will ultimately need to use a variety of tools to balance the power system. Thus the role of demand-side management with energy storage will be paramount to integrate future diverse generation portfolios. Electric water heating has been studied previously, particularly at the domestic level to provide load control, peak shave and to benefit end-users financially with lower bills, particularly in vertically integrated monopolies. In this paper a number of continuous direct load control demand response based electric water heating algorithms are modelled to test the effectiveness of wholesale electricity market signals to study the system benefits. The results are compared and contrasted to determine which control algorithm showed the best potential for energy savings, system marginal price savings and wind integration.

13/02394 Large-scale utilization of wind power in China: obstacles of conflict between market and planning

Zhao, X. *et al. Energy Policy*, 2012, 48, 222–232.

The traditional strict planning system that regulates China's power market dominates power industry operations. However, a series of market-oriented reforms since 1997 call for more decentralized decision-making by individual market participants. Moreover, with the rapid growth of wind power in China, the strict planning system has become one of the significant factors that has curtailed the generation of wind power, which contradicts with the original purpose of using the government's strong control abilities to promote wind power development. This paper first presents the reasons why market mechanisms are important for large-scale utilization of wind power by using a case analysis of the north-east grid, and then illustrates the impact of conflicts between strict planning and market mechanisms on large-scale wind power utilization. Last, the paper explores how to promote coordination between markets and planning to realize large-scale wind power utilization in China. It is argued that important measures include implementing flexible power pricing mechanisms instead of the current fixed pricing approach, formulating a more reasonable mechanism for distributing benefits and costs, and designing an appropriate market structure for large-scale wind power utilization to promote market liquidity and to send clear market equilibrium signals.

13/02395 Scaled ice accretion experiments on a rotating wind turbine blade

Han, Y. *et al. Journal of Wind Engineering and Industrial Aerodynamics*, 2012, 109, 55–67.

This work presents ice accretion tests of a model wind turbine blade mounted on a rotor test stand. The model test blade was scaled to reproduce local flow and icing conditions at the 95% radial station of the NREL Phase VI rotor. A modified Ruff scaling method was implemented to scale atmospheric icing conditions that could be generated in a laboratory facility. Scaling laws allowed for reduced testing time as well as a reduced chord length of the blades compared to on-site icing events were implemented. Classical blade element momentum theory (BEMT) was utilized to correlate inflow conditions at the test facility to actual operating conditions of the NREL Phase VI rotor. Experimentally obtained rime ice shapes are compared to LEWICE predictions and are used to validate the capability of the facility to reproduce representative icing conditions. The rime ice results matched with predictions to within 1% of both ice thickness and ice extent along the blade surfaces. The effects of angle-of-attack, temperature, liquid water content, and icing time on the final ice shapes were investigated in a parametric study. Experimentally obtained glaze ice shapes are used to demonstrate the severity of the icing events on wind turbine torque. The present work comprises testing procedures and experimental data that can be used for future efforts in ice accretion modelling and testing.

13/02396 Synthetic ester transformer fluid: a total solution to windpark transformer technology

Al-Amin, H. *et al. Renewable Energy*, 2013, 49, 33–38.

Synthetic ester transformer fluid has the ability to substantially reduce the risk associated with operational on/off-shore transformers. In comparison to alternative dielectrics such as cast resin, silicone fluid and natural ester, synthetic ester has proven to be the most suitable transformer dielectric. This paper presents evidence to support these claims.

13/02397 The ideal power curve of small wind turbines from field data

Trivellato, F. *et al. Journal of Wind Engineering and Industrial Aerodynamics*, 2012, 107–108, 263–273.

The present study aims at assessing the ideal power curve of fixed-speed, passive stall, small horizontal axis wind turbines from turbulent field data. The ideal power curve refers to ideal conditions (e.g. the wind is steady, laminar, spatially uniform and undisturbed by the turbine; no yaw error; the power output is intended in steady state). The ideal power curve has two main applications: the prediction of the wind energy that can be captured and the extension of the power curve to sites having different turbulence levels from the primitive test site. A 12 kW fixed-speed wind turbine was monitored for two years in a fairly turbulent site; the power train of the turbine had no appreciable filtering effect on the wind fluctuations. The ideal power curve was analytically derived by a Taylor's expansion (whose convergence was enhanced by the Shanks' transformation) and by an accurate analytical assumption of the ideal power coefficient. The present analytical solution is easy to handle and compared successfully to the IEC-based curve. The turbulence increases/diminishes the power output for velocities less/greater than the velocity at the inflection point of the power curve. Energy predictions by the ideal curve are within the inherent experimental error.

13/02398 The impacts of global climate changes on the wind power density in Brazil

Pereira, E. B. *et al. Renewable Energy*, 2013, 49, 107–110.

Brazil's wind energy production has escalated recently. However, the long-term wind projects do not include the yet unknown impacts of climate changes on wind power. This work is an assessment of these impacts by applying forecasts of a climate model and trend analysis over climatological time series from selected ground sites. Findings indicate a favourable scenario for wind power exploitation in Brazil on the long run.

13/02399 Wind power – an assault on local landscapes or an opportunity for modernization?

Rygg, B. J. *Energy Policy*, 2012, 48, 167–175.

Wind power development has produced controversies in many places. Some people see wind power as a sustainable source of energy, others see it as destroying nature and landscapes. The opposition to wind power is often asserted to be from local forces and NIMBYism, and support to be based on the national and global benefits of increased supply of renewable energy. This paper challenges this view by analysing how local communities with established or planned wind power parks went through the process of developing wind power, what arguments they used and how they think about the wind power technology and its expected local effects. It was found that most of the arguments in favour of wind power development addressed local concerns regarding the economy, modernization, and employment opportunities and not a need for sustainable energy. The opposition to wind power development was not based on NIMBYism. Rather, many different arguments were used, and the features of the controversies were distinct to each community.

13/02400 Wind power integration in Aalborg Municipality using compression heat pumps and geothermal absorption heat pumps

Østergaard, P. A. *Energy*, 2013, 49, (1), 502–508.

Aalborg municipality, Denmark is investigating ways of switching to 100% renewable energy supply over the next 40 years. Analyses so far have demonstrated a potential for such a transition through energy savings, district heating (DH) and the use of locally available biomass, wind power and low-temperature geothermal resources. The analyses have also demonstrated that the municipality will still rely heavily on surrounding areas for electric load balancing assistance. With a departure in a previously elaborated 100% renewable energy scenario, this article investigates how absorption heat pumps (AHP) and compression heat pumps (HP) for the supply of DH impact the integration of wind power. Hourly scenario-analyses made using the EnergyPLAN model reveal a boiler production and electricity excess which is higher with AHPs than with HPs whereas condensing mode power generation is increased by the application of HPs rather than AHP.

Others, including economics

13/02401 A comparison of the drivers influencing farmers' adoption of enterprises associated with renewable energy

Tate, G. *et al. Energy Policy*, 2012, 49, 400–409.

A declared target of both the UK government and the European Union is to produce 15% of energy requirements from renewable sources by the year 2020; however the UK is very unlikely to achieve this. The Department for the Environment, Food and Rural Affairs (Defra) has identified the potential among the farming industry to help meet this objective but there is little published research on how organizations can successfully interact with farmers to achieve structural change. This paper reports the findings of a postal questionnaire survey of farmers in the West Midlands Region of the UK where principal component analysis revealed that personal, farm business, regulatory and behavioural drivers affected the rate of adoption of renewable energy (RE) enterprises. Of the 393 farmers who responded, 14% had adopted one or more enterprises associated with RE with solar energy production the most popular of the RE technologies available to farmers. The study found that the most influential personal level factors contributing to the adoption of RE and associated technologies were cognitive, such as level of education, but not administrative, such as the attractiveness of government schemes supporting RE and associated enterprises. Adopters also tended to be younger than non-adopters, perhaps reflecting the impact of long investment payback periods typically found with RE enterprises, they were involved with larger and more financially viable businesses that were more likely to trade as limited companies or family partnerships. Of current non-adopters, 66% might decide to invest in RE technologies over the next five years. For these potential adopters, it emerged that personal, farm business and behavioural factors were the most significant drivers though contrary to expectation current non adopters assessed the policy support framework more favourably than current adopters. The explanation of this seems to be connected with timing, in that two very positive and encouraging signals in relation to feed-in tariffs (2010) and the renewable heat incentive (2011) were underway or near introduction before this research took place.

13/02402 A techno-economic analysis of tidal energy technology

Johnstone, C. M. *et al. Renewable Energy*, 2013, 49, 101–106.

This paper demonstrates the many factors governing the selection of electrical power generation technologies. The primary objective is to have a portfolio of technologies which hedge against risk. The inclusion of the ‘cost of carbon’ or subsidy for non-carbon technologies signals a market willingness to pay a premium for low carbon electricity. This premium is estimated against the additional cost of renewable technologies entering the market. Uncertainty in fuel prices and inflation creates risk that fuel-consuming generation may be more expensive over their whole life than renewables, where a greater proportion of costs are in the construction. Tidal is one of the few clean energy resources to allow a finite amount of daily supply to be firmly contracted. The capital and operational costs of emerging technologies fall with maturity. Tidal generation is an immature technology and second-generation devices, e.g. CoRMaT, etc. offer the ability to make significant reductions to both capital and operating costs. This provides the ability for tidal power to produce electricity at a cost comparable to offshore wind.

13/02403 A versatile system for offshore energy conversion including diversified storage

Fiaschi, D. *et al. Energy*, 2012, 48, (1), 566–576.

Offshore applications allow us to exploit different renewable energy sources (wave, wind, solar) that are complementary each other, due to their statistical yearly distributions. This study considers an offshore platform for energy production from renewable energy sources coupled with three energy storage systems. The proposed offshore platforms use a compressed air energy storage to timely shift the electricity production from the demand. The performance of the system related to a north Tyrrhenian Sea location was evaluated by a simulation model developed integrating three different software packages (Matlab, EES, TRNSYS). The system was designed to produce 564 kWh on the 2 h a day where peak electricity demand takes place. The results showed that the system is able to produce 177,000 kWh per year. This offshore power plant is conceived for local users (tourist resorts, villages), especially if placed in small or medium islands, wishing to qualify for extensive use of renewable energy.

13/02404 Are green hopes too rosy? Employment and welfare impacts of renewable energy promotion

Böhringer, C. *et al. Energy Economics*, 2013, 36, 277–285.

In view of pressing unemployment problems, policy makers across all parties jump on the prospects of renewable energy promotion as a job creation engine which can boost economic well-being. The analytical model shows that initial labour market rigidities in theory provide some scope for such a double dividend. However, the practical outcome of renewable energy promotion might be sobering. The computable general equilibrium analysis of subsidized electricity production from renewable energy sources (RES-E) in Germany suggests that the prospects for employment and welfare gains are quite limited and hinge crucially on the level of the subsidy rate and the financing mechanism. If RES-E subsidies are financed by labour taxes, welfare and employment effects are strictly negative for a broad range of subsidy rates. The use of an electricity tax to fund RES-E subsidies generates minor benefits for small subsidy rates but these benefits quickly turn into significant losses as the subsidy rate exceeds some threshold value.

13/02405 Clean fuel-saving technology adoption in urban Ethiopia

Beyene, A. D. and Koch, S. F. *Energy Economics*, 2013, 36, 605–613.

The heavy dependence and inefficient utilization of biomass resources have contributed to the depletion of forest resources in Ethiopia, while the use of traditional cooking technology has also been linked to indoor air pollution and poor health. In response, the government and other institutions have pushed for the adoption of new cooking technologies, with limited success. This research examines the reasons underpinning the lack of widespread adoption, via duration analysis, correlating the speed of adoption of Mirte and Lakech cook stoves – two examples of new cooking technologies – in urban Ethiopia to socioeconomic factors. According to the duration analysis, adoption rates have steadily increased over time, while economic factors, such as product price, household income and household wealth, are, for the most part, important determinants of adoption behaviour. There is also evidence that the availability of substitute technologies tends to hinder adoption, and that there are large regional differences in adoption rates, suggesting the need for a more detailed regional analysis of adoption decisions.

13/02406 Contribution of re-regulation reservoirs considering pumping capability to environmentally friendly hydropower operation

Pérez-Díaz, J. I. *et al. Energy*, 2012, 48, (1), 144–152.

Environmental constraints imposed on hydropower operation are usually given in the form of minimum environmental flows and maximum and minimum rates of change of flows, or ramp rates. One solution proposed to mitigate the environmental impact caused by the flows discharged by a hydropower plant while reducing the economic impact of the above-mentioned constraints consists in building a re-regulation reservoir, or afterbay, downstream of the power plant. Adding pumping capability between the re-regulation reservoir and the main one could contribute both to reducing the size of the re-regulation reservoir, with the consequent environmental improvement, and to improving the economic feasibility of the project, always fulfilling the environmental constraints imposed to hydropower operation. The objective of this paper is studying the contribution of a re-regulation reservoir to fulfilling the environmental constraints while reducing the economic impact of said constraints. For that purpose, a revenue-driven optimization model based on mixed integer linear programming is used. Additionally, the advantages of adding pumping capability are analysed. In order to illustrate the applicability of the methodology, a case study based on a real hydropower plant is presented.

13/02407 Curtailment of renewable generation: economic optimality and incentives

Jacobsen, H. K. and Schröder, S. T. *Energy Policy*, 2012, 49, 663–675.

The loss from curtailing generation based on renewable energy sources is generally seen as an unacceptable solution by the public. The main argument is that it is a loss of green energy and an economic loss to curtail generation with near zero marginal costs. However, this view could lead to overinvestment in grid infrastructure and underinvestment in renewable energy sources. This paper argues that some curtailment of fluctuating (variable) generation is optimal. The authors address the possible contributions to total curtailment from involuntary and voluntary curtailment. The costs of curtailment in terms of lost generation are discussed based on market price and support levels including the rationale for compensating generators for losses. The extent of actual curtailment is illustrated by examples from different global markets. In general, both the value of the curtailed energy and the amount of curtailed energy relative to total fluctuating generation is low but rising. Single generators may be affected considerably if insufficient compensation measures are in place. In the future, optimal curtailment will increase along with an increased share of fluctuating renewable generation. Extending renewable generation comparatively cheaply can be achieved by the installation of additional capacity at offshore locations until optimal curtailment levels are reached.

13/02408 Diffusion of renewable heating technologies in households. Experiences from the Norwegian household subsidy programme

Bjørnstad, E. *et al. Energy Policy*, 2012, 48, 148–158.

A sample of 896 Norwegian households participating in a subsidy programme was surveyed in order to evaluate the success of the programme. The programme subsidized investments in new heating technologies, including heat pumps and pellet stoves. The success of the programme was measured by the degree of overall satisfaction with the investment by the sampled households. Theories on diffusion of innovations and planned behaviour motivate the empirical modelling of the investment satisfaction. The economic return on the investment varied substantially both within and between the two heating technologies, with heat pumps outperforming pellet stoves in this respect. Still, the economic return showed no explanatory power toward the investment satisfaction of the household. Among the economic variables, only the electricity price had any influence on investment satisfaction. Technical quality, indoor climate and heat comfort, and the availability of the supplier of the heating equipment were the most important explanatory variables.

13/02409 Economic and energy evaluation of a logistics system based on biomass modules

An, H. and Searcy, S. W. *Biomass and Bioenergy*, 2012, 46, 190–202.

A biomass logistics system using large packages of sufficient size and density to maximize legal highway loads and rapid load/unload times was expected to minimize feedstock costs. Such a system has been field tested conceptually at Texas A&M University, but modelling was used to predict system performance prior to design of prototypes. Integrated Biomass Supply and Logistics (IBSAL), logistics system simulation software developed by the US Department of Energy, was employed to build a simulation model of the conceptual system. The new machine concepts required development of new IBSAL elements to model machine functions. Through a sensitivity analysis, the significance of several factors associated with the design and performance of the conceptual machines was evaluated. The estimated logistics cost ranges from \$19.65 to \$41.26 Mg^{-1}. The dry matter density of biomass modules, the operating efficiency of the forage harvester, and the travel speed of the module hauler proved to be the most influential factors for the system performance, and provide insights into design requirements.

13/02410 Efficient storage capacity in power systems with thermal and renewable generation

Steffen, B. and Weber, C. *Energy Economics*, 2013, 36, 556–567.

Power systems with high shares of wind and solar power have to balance their intermittent nature. Pumped-hydro storage plants can provide the required flexibility, while thermal backup plants offer an alternative. This paper proposes a capacity planning model to describe the efficient technology portfolio. It is evident that power systems with high shares of wind and solar power require a significant ‘backup’ capacity of controllable plants to step in when wind and solar radiation are low. This aspect is included into the analysis by means of a residual load duration curve that becomes steeper with higher renewable energy sources shares, and is highly visible in the results of an empirical case study for Germany: the required capacity of controllable plants is almost the same in all renewable scenarios (even though the technology mix changes) – if renewable generation covers 60% of the total demand (tripled compared to the 20% base case), the required ‘backup’ capacity reduces by only 6%. The analysis emphasizes that excess renewable generation in ‘high wind–low load’ situations does not necessarily mandate higher storage capacity. The surplus might as well be captured by existing storage plants, which in turn reduce the transformation of thermal base-load generation to peak-load power, the use case for which they have been initially built. As long as excess generation is not too big, the question of additional storage capacity instead has to be regarded with respect to changes in the shape of the residual load curve. The case study for Germany shows that steeper load duration curves potentially increase the efficient storage capacity by more than 50%. At the same time, CO_2 prices are a major driver of storage efficiency.

13/02411 Emissions of carbon monoxide and carbon dioxide from uncompressed and pelletized biomass fuel burning in typical household stoves in China

Wei, W. *et al. Atmospheric Environment*, 2012, 56, 136–142.

Carbon dioxide (CO_2) and carbon monoxide (CO) impact climate change and human health. The uncertainties in emissions inventories of CO_2 and CO are primarily due to the large variation in measured emissions factors (EFs), especially to the lack of EFs from developing countries. China's goals of reducing CO_2 emissions require a maximum utilization of biomass fuels. Pelletized biomass fuels are well suited for the residential biomass market, providing possibilities of more automated and optimized systems with higher modified combustion efficiency (MCE) and less products from incomplete combustion. However, EFs of CO_2 and CO from pellet biomass fuels are seldom reported, and a comparison to conventional uncompressed biomass fuels has never been conducted. Therefore, the objectives of this study were to experimentally determine the CO_2 and CO EFs from uncompressed biomass (i.e. firewood and crop residues) and biomass pellets (i.e. pine wood pellet and corn straw pellet) under real residential applications and to compare the influences of fuel properties and combustion conditions on CO_2 and CO emissions from the two types of biomass fuels. For the uncompressed biomass examples, the CO_2 and CO EFs were 1649.4 ± 35.2 and $47.8 \pm 8.9\ \mathrm{g\,kg^{-1}}$, respectively, for firewood and 1503.2 ± 148.5 and $52.0 \pm 14.2\ \mathrm{g\,kg^{-1}}$, respectively, for crop residues. For the pellet biomass fuel examples, the CO_2 and CO EFs were 1708.0 ± 3.8 and $4.4 \pm 2.4\ \mathrm{g\,kg^{-1}}$, respectively, for pellet pine and 1552.1 ± 16.3 and $17.9 \pm 10.2\ \mathrm{g\,kg^{-1}}$, respectively, for pellet corn. In rural China areas during 2007, firewood and crop residue burning produced 721.7 and 23.4 million tons of CO_2 and CO, respectively.

13/02412 Examining the cost efficiency of Chinese hydroelectric companies using a finite mixture model

Pestana Barros, C *et al. Energy Economics*, 2013, 36, 511–517.

This paper evaluates the operational activities of Chinese hydroelectric power companies over the period 2000–2010 using a finite mixture model that controls for unobserved heterogeneity. In so doing, a stochastic frontier latent class model, which allows for the existence of different technologies, is adopted to estimate cost frontiers. This procedure not only enables us to identify different groups among the hydro-power companies analysed, but also permits the analysis of their cost efficiency. The main result is that three groups are identified in the sample, each equipped with different technologies, suggesting that distinct business strategies need to be adapted to the characteristics of China's hydro-power companies. Some managerial implications are developed.

13/02413 Impacts of biodiesel on the Brazilian fuel market

Silva Junior, D. *Energy Economics*, 2013, 36, 666–675.

This paper investigates market effects of the Brazilian biodiesel law, which made the use of biodiesel, blended with petroleum diesel, mandatory in Brazil. The study estimates the demand curve for diesel fuel (biodiesel and petroleum diesel) and the industry supply curve of biodiesel. These two pieces of information have been used in a static analysis to draw scenarios with different biodiesel mandates. The results show that the current proportion of biodiesel in the diesel mixture (5%) increases consumers' price by 1.7% and decreases the consumption by 1.5% compared to the scenario without biodiesel. Also, an increase in the biodiesel percentage to 10% would raise the price by 3.5% and reduce the consumption by 3%.

13/02414 Modeling and optimization of a hybrid system for the energy supply of a ‘green’ building

Dagdougui, H. *et al. Energy Conversion and Management*, 2012, 64, 351–363.

Renewable energy sources (RES) are an ‘indigenous’ environmental option, economically competitive with conventional power generation where good wind and solar resources are available. Hybrid systems can help in improving the economic and environmental sustainability of renewable energy systems to fulfil the energy demand. A dynamic decision model for the energy management of a household is proposed in this study. The model is able to define the optimal energy flows management in a building characterized by a mix of renewable energy resources (solar, biomass, wind) to satisfy different demands (electric, heating and water). This model was developed and applied to a household located at Capo Vado (Liguria Region). Optimal results to satisfy all the energy demands are found for a testing day with presence/absence of the storage system. Moreover, an analysis about the avoided emissions is reported and the importance of having a storage system is also demonstrated. The developed decision model can also be used for real-time management, through a model predictive control approach that is adopted for the dynamic decision model solution. It should be noted that, in the case of absence of the energy storage system, since there are no state equations and available energy varies in each time interval, the optimization problem can be run at each time interval in a separated way, and is in fact static. Future developments of this work concern the possibility of introducing stochastic issues both in demand and resource predictions. In this case, in order to reduce the overall complexity of the problem, dynamic programming could be used. Then, the model could be detailed from the electrical, thermal and technological point of view. Moreover, an objective function based on energy prices could also be adopted in order to consider the green-building as an energy producer. Moreover, a multi-objective approach could be formalized to take into account economic and environmental issues, as well as the objectives weighted in the current version of the objective function. Finally, the inclusion of the developed dynamic decision model in a decision support system that can allow the user to interact with the mathematical models could be helpful for the energy management of the household.

13/02415 Optimising transport efficiency and costs in Australian wood chipping operations

Acuna, M. *et al. Biomass and Bioenergy*, 2012, 46, 291–300.

This paper examines the optimization of the transport scheduling of woodchips for in-field chipping operations whose efficiency depends on a range of factors. It illustrates the advantages of optimizing trucking efficiency and cost in the context of the Australian forest industry. The study was enabled using an adapted version of simulated annealing and a forestry domain model, and a simulator based on them, called Fast Truck, was implemented for experimental use. Insights arising from the simulator results are discussed in the context of the Australian industry. The factors worth noting are truck payload and chipper utilization, which by optimization, account for 52% and 29% of the total cost savings obtained, respectively. These savings arise when better transport control and management occur in chipping operations.

Further work will consider ways to implement these optimizations, primarily, by adapting Fast Truck as an optimizer of daily dispatch schedules.

13/02416 Optimum sizing of stand-alone wind-photovoltaic hybrid systems for representative wind and solar potential cases of the Greek territory

Kaldellis, J. K. and Zafirakis, D. *Journal of Wind Engineering and Industrial Aerodynamics*, 2012, 107–108, 169–178.

Wind and solar driven stand-alone systems can under certain conditions comprise attractive electrification solutions for numerous isolated consumers worldwide. However, due to their requirement for considerable energy storage capacity, diesel generator sets are normally used instead. To minimize oil consumption, the idea of creating a combined wind – photovoltaic (PV) based hybrid system with the use of an appropriate energy storage device is currently investigated. In this context, the main target of the specific work is to estimate the appropriate size of a similar system, so as to meet the energy demand of typical remote consumers under the criterion of minimum first installation cost. Representative case studies of the Greek territory with different quality of wind and solar potential are currently investigated, with the results obtained designating the advantages of the proposed solution, especially for locations of low wind potential. Furthermore, according to the results, the critical role of the local wind potential on the optimum size of such configurations is reflected, while variation of the local solar potential in the Greek territory seems to only slightly influence the minimum first installation cost solutions.

13/02417 Photovoltaic and wind energy systems monitoring and building/home energy management using ZigBee devices within a smart grid

Batista, N. C. *et al. Energy*, 2013, 49, (1), 306–315.

The actual electric grid was developed to offer electricity to the clients from centralized generation, so with large-scale distributed renewable generation there is an urgent need for a more flexible, reliable and smarter grid. The wireless technologies are becoming an important asset in the smart grid, particularly the ZigBee devices. These smart devices are gaining increased acceptance, not only for building and home automation, but also for energy management, efficiency optimization and metering services, being able to operate for long periods of time without maintenance needs. In this context, this paper provides new comprehensive field tests using open source tools with ZigBee technologies for monitoring photovoltaic and wind energy systems, and also for building and home energy management. The experimental results demonstrate the proficiency of ZigBee devices applied in distributed renewable generation and smart metering systems.

13/02418 Policy incentives for switchgrass production using valuation of non-market ecosystem services

Chamberlain, J. F. and Miller, S. A. *Energy Policy*, 2012, 48, 526–536.

This study presents a linear profit model with combined economic and environmental factors for a switchgrass-for-biofuels agricultural system in the south-eastern USA. The objectives are to establish conversion-to-switchgrass thresholds for various market prices and identify policy incentives that would ensure economic profit while also maximizing environmental benefits (carbon sequestration, displacement of fossil fuels) and minimizing negative impacts (global warming potential, nitrate loss). Weighting factors are chosen to represent incentives and penalties by assigning value to the impacts. With no other incentives, switchgrass market prices of at least $51 and $58/dton would be needed in order to make a profitable switch from corn/conservation reserve programme lands and cotton, respectively. At a mid-range offering of $50/dton, feasible carbon credit prices of $3, $8, $23 per metric tonne CO_2e would incentivize conversion from corn, CRP, or cotton, respectively. Similarly, a water quality penalty of $0.20, $3, $2 per kilogram NO_3–N leached would incentivize the same conversions with resultant watershed improvement. At a lower price of $30/dton switchgrass, incentives based on valuation of ecosystem services begin to exceed feasible ranges of these valuations.

13/02419 Potential renewable oxygenated biofuels for the aviation and road transport sectors

Jenkins, R. W. *et al. Fuel*, 2013, 103, 593–599.

Currently two major biofuels are present in the global fuel market; bioethanol which is largely produced by the fermentation of sugars or starches and biodiesel which is produced from the transesterification of vegetable oils such as rapeseed, soybean or palm. A number of key issues limit the applicability of these biofuels as substitutes in the road transport sector. These include the insufficient land area required to grow the feedstock needed alongside food crops, for bioethanol the poor energy density and for biodiesel the variability of the resulting fuel depending on the source and growing conditions, the oxidative instability of most biodiesel fuels and the poor low temperature behaviour. This last issue also limits the applicability of these esters in the aviation sector. In an attempt to address these issues a range of possible renewable fuels were synthesized from esterified fermentation products potentially derivable from cellulosic sugars. These monoesters and diesters were then examined for their potential as a replacement for aviation kerosene, mineral diesel or petrol. To determine the most suitable replacements, where appropriate, the fuels density, kinematic viscosity, melting point, boiling point, flash point, miscibility, solubility in water, the oxidative stability, lubricity and cetane number were examined and compared to their fossil fuel counterparts. From this study it emerges that the majority of the dibutyl diesters have physical properties which make them ideal replacements for diesel fuel, with the exception of the cetane number, where blends with diesel or cetane improving additives would need to be used to bring the fuels up to specification. Butyl butyrate has the potential to be used in a blend with petrol and was the only fuel tested fully compatible with aviation kerosene. The fuels tested also displayed superior lubricity to other alternative hydrocarbon fuels and as such have the potential to be used as additives for hydrocarbon fuels.

13/02420 Relations for a periodic array of flap-type wave energy converters

Renzi, E. and Dias, F. *Applied Ocean Research*, 2013, 39, 31–39.

This paper investigates the interaction of plane incident waves with a wave farm in the open ocean. The farm consists of a periodic array of large flap-type wave energy converters. A linear inviscid potential-flow model, already developed by the authors for a single flap in a channel, is considered. Asymptotic analysis of the wave field allows one to obtain new expressions of the reflection, transmission and radiation coefficients of the system. It is shown that, unlike a line of heaving buoys, an array of flap-type converters is able to exploit resonance of the system transverse modes in order to attain high capture factor levels. Relations between the hydrodynamic coefficients are derived and applied for optimizing the power output of the wave farm.

13/02421 Short-term optimal operation of Three-gorge and Gezhouba cascade hydropower stations in non-flood season with operation rules from data mining

Ma, C. *et al. Energy Conversion and Management*, 2013, 65, 616–627.

Information hidden in the characteristics and relationship data of a cascade hydropower stations can be extracted by data-mining approaches to be operation rules and optimization support information. In this paper, with Three-gorge and Gezhouba cascade hydropower stations as an example, two operation rules are proposed due to different operation efficiency of water turbines and tight water volume and hydraulic relationship between two hydropower stations. The rules are applied to improve optimization model with more exact decision and state variables and constraints. They are also used in the population initiation step to develop better individuals with culture algorithm with differential evolution as an optimization method. In the case study, total feasible population and the best solution based on an initial population with an operation rule can be obtained with a shorter computation time than that of a pure random initiated population. Amount of electricity generation in a dispatch period with an operation rule also increases with an average increase rate of 0.025%. For a fixed water discharge process of Three-gorge hydropower station, there is a better rule to decide an operation plan of Gezhouba hydropower station in which total hydraulic head for electricity generation is optimized and distributed with inner-plant economic operation considered.

13/02422 Techno-economic analysis of bioethanol production in Africa: Tanzania case

Quintero, J. A. *et al. Energy*, 2012, 48, (1), 442–454.

In this paper a techno-economic analysis for bioethanol production in Africa for Tanzania case is presented. It is shown conversion pathways from sugar cane juice and molasses, at three levels of technological schemes, where the first one includes a selection of widely conventional technologies, the second level with a more sophisticated fermentation technology and the third level using a different broth and solid treatment for ethanol production. A simulation procedure was taking into account in order to evaluate the conversion pathways schemes using different scenarios of raw material pretreatment, using Aspen Plus software, that include productivity analysis and energy requirements for each process configuration. Also an economical evaluation of each technology level and each scenario is shown. A comparison and discussions for each technological level and each scenario for bioethanol production in Tanzania is presented. These results served as the basis to draw recommendations on technological and economic feasibility aspects for the implementation of a national biofuel production programme in Africa. The study helped to identify the best technological schemes for producing fuel-grade alcohol from the various raw materials analysed.

13/02423 The prospects of cost reductions in willow production in Sweden

Rosenqvist, H. *et al. Biomass and Bioenergy*, 2013, 48, 139–147.

The current and future costs of willow short rotation coppice production in Sweden are analysed, considering all relevant cost factors explicitly. The future production costs are estimated considering effects of coppice area expansion and learning. The current and future costs of land and of risk premiums are subsequently estimated. Subsidies for farmers are not considered. If the area of willow cultivation were to expand enough to generate economies of scale, the production cost could be cut by about 10% compared to the current level. When learning effects are also considered, the total cost reduction potential is about 35%. Two major cost components (fertilization and road transport) are roughly stable while two other major cost components (establishment and harvest) have larger prospects for cost reduction, primarily due to potential for learning. Land costs and risk premiums vary and are uncertain, but both are estimated to be potentially significant compared to other cost components. Requirements of risk premiums may become lower as a consequence of area expansion and learning. Land costs are subject to many factors that are inherently uncertain, not the least future food prices. Efficient policies promoting an expansion of willow cultivation are discussed.

13/02424 Wind powered pumped-hydro storage systems for remote islands: a complete sensitivity analysis based on economic perspectives

Kapsali, M. *et al. Applied Energy*, 2012, 99, 430–444.

The electrification of the non-interconnected Greek islands is mainly based on autonomous power stations (APSs) that are characterized by considerably high electricity production cost, whilst, in several cases, problems related with power shortage are encountered. At the same time, the contribution of wind energy is significantly restricted due to electrical grid limitations imposed to 'secure' the stability of the local network and thus resulting in significant rejected wind energy amounts. On the basis of sensitivity analysis, the present study evaluates the techno-economic viability of a system that incorporates the simultaneous operation of existing and new wind farms (WFs) with pumped storage and hydro turbines, which are able to provide the electrical grid of a remote island with guaranteed energy amounts during the peak load demand hours on a daily basis. The performance of the system is simulated during a selected time period for various system configurations and an attempt is made to localize the optimum solution by calculating various financial indices. Emphasis is given on the conduction of an extensive sensitivity analysis considering three main variables (i.e. produced energy selling price, the percentage of state subsidization and the price of the wind energy surplus bought from the already existing WFs) taking also into account several constraints of the national legislation. Based on the most economically viable (payback period quite less than 10 years) configuration derived (24 MW WFs, 15 MW water pumping system, 13.5 MW hydro turbines), the contribution of renewable energy increases by almost 15% (in absolute terms) compared to current conditions, reaching about 25% of the island's energy consumption pattern. The proposed analysis may be equally well applied to every remote island possessing remarkable wind potential and appropriate topography.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

13/02425 A new approach to predict the excitation current and parameter weightings of synchronous machines based on genetic algorithm-based *k*-NN estimator

Kahraman, H. T. *et al. Energy Conversion and Management*, 2012, 64, 129–138.

This paper presents a novel and efficient solution to overcome difficulties in excitation current estimation and parameter weighting of synchronous motors. Weighting the parameters or searching the best coefficients of problems is commonly accomplished through intuitive/heuristic approaches. For this reason, in this study, a genetic algorithm-based *k*-nearest neighbour estimator (also called intuitive *k*-NN estimator, IKE) is adapted to explore the optimum parameters and this algorithm estimates the excitation current of a synchronous motor with having small prediction errors. The motor parameters such as load current, power factor, error and excitation current changes are weighted depending on the effects on the excitation current. The experimental results are compared with the estimation results in consideration with standard deviations of the well-known artificial neural network-based (ANN) method and *k*-NN-based estimator with that of the proposed IKE method. The results have shown that the proposed IKE estimator achieves the tasks in high accuracies, stabilities, robustness and low error rates other two well-known methods presented in the literature.

13/02426 Ammonia–water absorption cycle on three-dimensional graphs – the *Absorption 3D* tool software

Kasperski, J. and Eichler, J. *International Journal of Refrigeration*, 2012, 35, (7), 1958–1966.

Designing of an absorption machine with ammonia–water solution as a working fluid requires the application of two-dimensional graphs showing properties of that solution. The most suitable graphs are h–ξ, s–ξ and lg p^{-1}/T. On the two-dimensional graph, a set of isolines are presented according to the third thermodynamical parameter in which the axis is hidden. Modern computer technology enables a dynamic creation of three-dimensional graphs. An interactive working mode strongly stimulates the user perception. Considering ammonia–water solution, three-dimensional graphs aid a comprehension study of the absorption machine properties. The computer software called *Absorption 3D* tool was developed and designed by the authors. The software enables a three-dimensional visualization of the processes on solution properties graphs. The purpose of the software is to support the educational process, and it is especially suitable for students and lecturers of refrigeration machine division. The software is also a useful tool for engineers and scientific workers.

13/02427 An improved generalized three-parameter cubic equation of state for pure fluids

Guria, C. and Pathak, A. K. *Journal of Petroleum Science and Engineering*, 2012, 96–97, 79–92.

An improved simple generalized three-parameter cubic equation of state for pure fluids is proposed to estimate pure component fluid properties by incorporating substance dependent epsilon-function and almost substance independent sigma-function in the generic cubic equation of state, followed by temperature and acentric factor dependent attractive term. The proposed cubic equation of state is utilized to predict critical compressibility factor, liquid molar volume, vapour molar volume, and pure component vapour pressure for several simple hydrocarbons and fatty acid of methyl esters, and the predicted properties are compared with the actual values. In this study, most of the pure fluid properties are considered from literature; however experimentation is carried out for few fatty acid of methyl esters to determine pure fluid vapour pressure at elevated temperature and pressure. The proposed cubic equation of state is found to be accurate in predicting both literature reported and experimentally determined pure fluid properties. The overall performance of the proposed cubic equation of state is also compared with commonly used cubic equations of state and is found to be superior for predicting critical compressibility factors and other pure fluid properties.

13/02428 Biomimetics of stabilized earth construction: challenges and opportunities

Reddi, S. *et al. Energy and Buildings*, 2012, 55, 452–458.

This state-of-the-art paper is based on the premise that skin vasculature holds several important clues on how energy-efficiency could be accomplished in indoor environments. It is also based on the premise that stabilized earth, which has been extensively used throughout the world as a construction material, could be engineered to mimic the evolutionary developments in biology. The paper begins with a summary of recent developments in plant physiology and skin vasculature, and applies these developments in the context of stabilized earth construction. A number of interdisciplinary research opportunities are identified for communities engaged in building and energy research. This paper is developed from the proceedings of an international workshop on biomimetics of stabilized earth construction, held in Reading, UK, in March 2011. In particular, connections forged between the following disciplines would be essential to formalize the branch of biomimetics of civil infrastructure: (i) geotechnical engineering, which involves a formal study of the engineering and environmental behaviour of soils, both natural and engineered, at pore-scale and Darcy-scale; (ii) sensing technologies to assess the thermoregulatory behaviour of the engineered soils systems reinforced with organic fibres, and (iii) a basic/fundamental knowledge of specific biological systems where thermoregulatory behaviour has evolved over aeons of time. Such connections will open up a series of research efforts involving modelling investigations on heat transfer/exchange in soil-fibre composites, engineered pore architectures in stabilized soils, up-scaling investigations, structural characterization and improvement, and field-scale implementation and performance.

13/02429 Compositional data analysis in the study of integrated geochemical anomalies associated with mineralization

Zuo, R. *et al. Applied Geochemistry*, 2013, 28, 202–211.

Geochemical data are typical compositional data which should be opened prior to univariate and multivariate data analysis. In this study, a frequency-based method (robust principal component analysis, RPCA) and a frequency-space-based method (spectrum–area fractal model, S–A) are applied to explore the effects of the data closure problem and to study the integrated geochemical anomalies associated with polymetallic Cu mineralization using a stream sediment geochemical dataset collected from the Zhongteng district, Fujian Province (China). The results show that: (1) geochemical data should be opened prior to RPCA to avoid spurious correlation between variables; (2) geochemical pattern is a superimposition of multi-processes and should be decomposed; and (3) the S–A fractal model is a powerful tool for decomposing the mixed geochemical pattern.

13/02430 Effects of liquid compressibility on radial oscillations of gas bubbles in liquids

Zhang, Y.-n. and Li, S.-c. *Journal of Hydrodynamics, Ser. B*, 2012, 24, (5), 760–766.

For forced radial oscillations of gas bubbles in liquids, a more rigorous expression of the acoustic damping constant based on Keller's equation is developed. Comparison with those in published papers is also made. The expression offered in this paper will improve the predictions of total damping constant in particular for high frequencies and large bubbles, i.e. large $\omega R_0/c_1$ (ω is the frequency of driving sound field, R_0 is the equilibrium bubble radius, c_1 is the sound speed in the liquid). Examples in ultrasound imaging and acoustical oceanography are demonstrated.

13/02431 Electrically driven light emission from a single suspended carbon nanocoil

Ma, H. *et al. Carbon*, 2012, 50, (15), 5537–5542.

Electrically driven thermal radiation spectra from single suspended carbon nanocoils (CNCs) were investigated. The suspended CNC, whose structure is a hybrid between sp^2 graphite-like nanocrystallites and sp^3 amorphous carbon, shows thermally excited emission peaks superimposed on the blackbody radiation spectrum for wavelengths above 600 nm. It is believed that at least four pairs of energy bands exist around the Fermi energy level and the observed emission peaks are attributed to thermally-excited interband electron transitions in the CNC. Photoluminescence measurements for the CNCs show similar emission peaks to the thermally excited emission, which further supports speculation on the electronic structure of the CNC.

13/02432 Estimation of heat flux and temperature field during drilling process using dynamic observers based on Green's function

de Sousa, P. F. B. *et al. Applied Thermal Engineering*, 2012, 48, 144–154.

This study presents an inverse technique to estimate temperature and heat flux at the tool–piece interface during drilling process. The technique used a method based on Green's function and dynamic observers. While most works found in literature focused the tool, in this study the work piece was modelled thermally. The thermal model was obtained by numerical solution of the transient three-dimensional heat diffusion equation considering the drill as a moving heat source. Two numerical simulations were performed in order to evaluate the thermal model, the inverse algorithm and to locate measurement regions with low sensitivity. Finite volumes method was used to solve the heat diffusion equation. Experimental tests were performed using cemented carbide tool to drill a micro-alloyed steel workpiece (high-strength low-alloy steel). The heat flux generated at the cutting interface during the drilling process was estimated using the developed inverse technique and only experimental data from the heating period was used. After heat flux estimation the temperature field was calculated. Comparisons between experimental and estimated data present a good accordance for the thermocouples not used in the heat flux estimation.

13/02433 Metal plate target design for the lead slowing down time spectrometer (LSDTS)

Park, C. J. *et al. Annals of Nuclear Energy*, 2012, 49, 218–222.

A better technology for lead slowing down time spectrometer (LSDTS) has been developed to quantify the fissile isotopes in any kind of nuclear fuels. A linear electron accelerator is usually considered due to its high efficiency neutron production and a flexible size depending on the beam power. Neutrons produced from the collision between the electron beam and a metal target propagate into the lead medium and finally react with the fissile isotope. In order to have a marginal resolution of the induced fission neutron from the fissile isotope and to have a high statistical accuracy of the measured signal for fissile isotope analysis, it is required to have a high intensity neutron source through the proper target design. In this study, several sensitivity tests of plate type targets are carried out with various materials, shapes, and geometries through Monte Carlo calculations. A few experiments have been also performed at the test linear accelerator at the Pohang Accelerator Laboratory with sample targets. From the results, the following findings are obtained: (a) among several metal targets, Ta, W, and U provide high neutron yields. Neutron spectrum follows a similar trend for various types of metal plate target geometries. (b) A target plate of a uniform radius with an increasing thickness provides better capability of neutron production for LSDTS system. (c) Radius variation does not make a significant effect on neutron production. (d) The middle part of the plate target releases the higher intensity of neutron. It requires a forced cooling system with a gas circulation, too. As a conclusion, an optimal target plate with an increasing thickness provides a better neutron yield when the electron beam is incident to the metal target such as Ta or W. It is expected that more detail works should be followed including thermal and mechanical analysis for behaviours of plate metal targets to complete the optimal target design of the LSDTS system.

13/02434 Microbial desalination cell with capacitive adsorption for ion migration control

Forrestal, C. *et al. Bioresource Technology*, 2012, 120, 332–336.

A new microbial desalination cell with capacitive adsorption capability (cMDC) was developed to solve the ion migration problem facing current MDC systems. Traditional MDCs remove salts by transferring ions to the anode and cathode chambers, which may prohibit wastewater beneficial reuse due to increased salinity. The cMDC uses adsorptive activated carbon cloth (ACC) as the electrodes and utilizes the formed capacitive double layers for electrochemical ion adsorption. The cMDC removed an average of 69.4% of the salt from the desalination chamber through electrode adsorption during one batch cycle, and it did not add salts to the anode or cathode chamber. It was estimated that 61–82.2 mg of total dissolved solids (TDS) was adsorbed to 1 g of ACC electrode. The cMDC provides a new approach for salt management, organic removal, and energy production. Further studies will be conducted to optimize reactor configuration and achieve *in situ* electrode regeneration.

13/02435 New approach for prediction of asphaltene precipitation due to natural depletion by using evolutionary algorithm concept

Ahmadi, M. A. and Shadizadeh, S. R. *Fuel*, 2012, 102, 716–723.

Asphaltene precipitation affects enhanced oil recovery processes through the mechanism of wettability alteration and blockage. Asphaltene precipitation is very sensitive to the reservoir conditions and fluid properties, such as pressure, temperature and injected fluid molecular weight. In this work, the model based on a feed-forward artificial neural network (ANN) optimized by particle swarm optimization (PSO) as an artificial intelligence modelling tool to predict asphaltene precipitation due natural depletion. Particle swarm optimization (PSO) is used to decide the initial weights of the neural network. The PSO–ANN model is applied to the experimental data from one of northern Persian Gulf oil field has been used to develop this model. The predicted results from the PSO–ANN model and BP–ANN were compared to the experimental precipitation data. The average relative absolute deviation between the model predictions and the experimental data was found to be less than 4%. A comparison between the prediction of this model and the alternatives showed that the PSO–ANN model predicts asphaltene precipitation more accurately.

13/02436 Predicting and optimization of energy consumption using system dynamics-fuzzy multiple objective programming in world heritage areas

Wu, Z. and Xu, J. *Energy*, 2013, 49, (1), 19–31.

Energy consumption and efficiency are important in regional low-carbon economic development and environmental protection. This paper provides a system dynamics and fuzzy multi-objective programming integrated approach for the prediction of energy consumption and CO_2 emissions at a regional level. First, a general system dynamics model is constructed to analyse an economy-energy system. To deal with the uncertainties and optimize the parameters in the system, a fuzzy multiple objective programming model is used. This decision support model is then applied to predict the energy consumption of a world heritage area in China during 2010–2020. The results reveal that the energy consumption and CO_2 emissions increase dramatically with rapid economic growth. In the scenario herein considered, which is based on the proposed optimization model, a 19.32% reduction was found in the energy intensity decreases from 0.88 tce/10^4 RMB to 0.71 tce/10^4 RMB, and a 23.26% reduction in the CO_2 emission intensity, from 2.15 t/10^4 RMB to 1.65 t/10^4 RMB. Policy suggestions such as adjusting the industrial structure, enhancing local hydro-power and renewable energy and increasing investment in energy technology and efficiency are indicated for the promotion of a low-carbon oriented economy in world heritage areas.

13/02437 Sierpinski's forest: new technology of cool roof with fractal shapes

Sakai, S. *et al. Energy and Buildings*, 2012, 55, 28–34.

This paper presents a new technology for constructing cool roofs composed of fractal shapes. The roofs consist of many Sierpinski tetrahedron units and block 100% sunlight from a particular direction. The sunlight from other directions partly penetrates the roof, creating a leafy shaded area under the roof. Compared with ordinary flat roofs, these roofs greatly reduce surface temperature and consequently provide a cool environment without strong heat radiation. The fractal structure of the tetrahedron units is similar to that of natural trees. Three-dimensional measurements revealed that natural trees have a fractal dimension of approximately 2, which is similar to that of the Sierpinski tetrahedrons. In this study, fractal roofs made from different materials were tested at two sites. The results showed that they were very effective in reducing surface temperatures in sunlight.

13/02438 Study on measurement and quantitative analysis of Radon-222 emitted from construction materials

Ju, Y.-J. *et al. Annals of Nuclear Energy*, 2012, 49, 88–95.

The air concentrations of radon and thoron (Rn-220) emitted to the atmosphere from four types of construction materials (brick, tile, red clay tile, and gypsum tile) were measured and analysed using continuous radon monitoring equipment (RTM 1688–2). Of the four samples examined, the cement brick showed the highest levels of radon emission, whereas the red clay tile showed the highest level of thoron emission. Gypsum tile showed the lowest radon and thoron emission. The level of radon emission was estimated based on the materials required for the construction per unit area (3.3 m^2) in an actual construction. The values for cement brick were highest at 10,875.0 Bq/m^3 for radon and 1,508.3 Bq/m^3 for thoron. The value for gypsum tile was lowest for radon (24.6 Bq/m^3), whereas the value for tile was lowest for thoron (21.0 Bq/m^3). This study suggests methods to examine the effects of radon and reduce the personal radiation exposure dose. Government should be active in publicizing and encouraging the use of construction materials with lower levels of radon emission.

13/02439 Systematic approach for the synthesis of water and energy networks

Martínez-Patiño, J. *et al. Applied Thermal Engineering*, 2012, 48, 458–464.

In this paper a heuristic procedure for the synthesis of integrated water and thermal energy networks is presented. The procedure is based on process integration techniques and looks at design of networks that exhibit minimum water and energy consumption. The interrelations between of water and energy are analysed and new insights are drawn that allow for the implementation of a systematic methodology. The approach starts with the use of a temperature vs concentration diagram from which the water using structure is designed. Starting from an initial network configuration, the structure is further improved in order to minimize the external resources requirements. In addition, the use of non-isothermal mixing allows the reduction in the number of required heat exchangers. A case study from the open literature is used to show the application of the procedure.

13/02440 The potential for online monitoring of short-term process dynamics in anaerobic digestion using near-infrared spectroscopy

Krapf, L. C. *et al. Biomass and Bioenergy*, 2013, 48, 224–230.

This work reports the development of a near-infrared (NIR) spectroscopy online calibration for monitoring volatile solids (VS) and total volatile fatty acids (VFA) process parameters during anaerobic digestion (AD). The objective was to investigate its potential to estimate the dynamics of AD process parameters after feeding events. A recirculation loop was employed to record online measurements during an 8-month experiment using a 3.3 m^3 pilot plant fed with maize silage under mesophilic conditions. Sampling was performed to conduct calibrations and subsequent test-set validations, comparing the NIR spectroscopy estimates to the reference values. The calibrated accuracy in terms of mean prediction errors (RMSEP) was 3 g kg^{-1} for VS and 0.9 g kg^{-1} for VFA in the fresh matter. By applying the calibrations to time series spectra, the model accuracy provided adequate indications of the concentration changes, including highly sensitive monitoring of short-term VFA dynamics.

13/02441 The use of small angle neutron scattering with contrast matching and variable adsorbate partial pressures in the study of porosity in activated carbons

Mileeva, Z. *et al. Carbon*, 2012, 50, (14), 5062–5075.

The porosity of a typical activated carbon is investigated with small angle neutron scattering (SANS), using the contrast matching technique, by changing the hydrogen/deuterium content of the absorbed liquid (toluene) to extract the carbon density at different scattering vector (Q) values and by measuring the p/p_0 dependence of the SANS, using fully deuterated toluene. The contrast matching data shows that the apparent density is Q-dependent, either because of pores opening near the carbon surface during the activation processor or changes in D-toluene density in nanoscale pores. For each p/p_0 value, evaluation of the Porod invariant yields the fraction of empty pores. Hence, comparison with the adsorption isotherm, shows that the fully dry powder undergoes densification when liquid is added. An algebraic function is developed to fit the SANS signal at each p/p_0 value hence yielding the effective Kelvin radii of the liquid surfaces as a function of p/p_0. These values, when compared with the Kelvin equation, show that the resultant surface tension value is accurate for the larger pores but tends to increase for small (nanoscale) pores. The resultant pore size distribution is less model-dependent than for the traditional methods of analysing the adsorption isotherms.

13/02442 Thermodynamic formulation of the constitutive equations for solids and fluids

Ferrari, A. and Mittica, A. *Energy Conversion and Management*, 2013, 66, 77–86.

A general thermodynamic approach to material constitutive equations is presented and analysed. The discussion is developed on piezoelectric and magnetostrictive materials as they pose modelling complexities that are suitable for the development of a comprehensive theory. The contributions of the work comprise: a general treatment of the problem, which includes kinetic energy, thermal effects and material internal dissipation in the energy balance; a simple matrix approach to clearly describe the thermoelastic, piezoelectric, pyroelectric, magnetostrictive and pyromagnetic relations; an analysis of the possible material properties involved in the definition of the constitutive equations; the introduction of a modified expression for the complementary strain–energy density, which allows the state equations commonly used in fluid dynamics to be derived from the constitutive equations obtained for piezoelectric crystals. Eight major options have been identified for the selection of the independent variables in piezoelectric non-linear crystals (the same holds for magnetostrictive materials), consequently, eight distinct thermodynamic potentials can generally be identified, resulting in eight different sets of constitutive equations. However, when linear materials are considered and thermal effects are disregarded, the thermodynamic potentials that can be used to derive the constitutive relations can always be reduced to a free-energy type function: this decreases the number of definable constitutive properties to a great extent. The developed concepts have been applied to evaluate the differences that can occur in the physical properties of solids and liquids as the operation mode changes from isothermal to adiabatic or from isochoric to isobaric. Significant differences have generally been observed between isothermal and isentropic values in the piezoelectric properties of materials that exhibit strong pyroelectric and thermal expansion effects. The thermal effects are generally unimportant for Young's modulus, whereas they are remarkable for bulk modulus of elasticity, even though the latter is a mechanical parameter of interest only for fluids. Finally, noteworthy differences have been found between the principal specific heats: the isobaric to isochoric specific heat ratio does not depend on the phase (whether liquid or solid), and should be evaluated case by case.

13/02443 Transient and steady-state analysis of heat, mass, and momentum transfer in developing and fully-developed regions of homogeneous tubular reactors with non-Newtonian fluid flow

Abbaszadeh Molaei, E. *et al. Energy Conversion and Management*, 2013, 65, 308–321.

In this paper, the problem of simultaneous heat, mass, and momentum transfer in the developing region of tubular reactors with homogeneous chemical reaction and laminar power-law fluid flow under unsteady-state conditions has been solved. In this regard, the general governing equations were solved using finite-difference method and analysed carefully. Moreover, the influences of various parameters and dimensionless numbers such as power-law index, heat of reaction, reaction order, and Damköhler number value on the numerical results were investigated. In addition, the numerical results obtained for the fully-developed velocity distribution of Newtonian fluid flow and Sherwood number value were validated against the well-known fully-developed velocity distribution and reported Sherwood number value in the literature and good agreement was obtained.

13/02444 Wind speed modelling using Weierstrass function fitted by a genetic algorithm

Barszcz, T. *et al. Journal of Wind Engineering and Industrial Aerodynamics*, 2012, 109, 68–78.

In this paper a wind speed model is presented as a time series. The main goal is to use it as a model of the load of wind turbine gears for simulation of real, varying operational conditions for wind turbine vibration modelling. Several wind characteristics for evaluation of the wind model accuracy in the context of a wind turbine gears load simulation are proposed. Verification of the hypothesis that wind speed as a time series has a fractal character is another aim of this paper. The Weierstrass functions family, whose graphs are fractal sets, in combination with medium-term trends, is used as the basis of the model. The function with a fractal component is fitted to the past observation data. A genetic algorithm is used as the fitting procedure. Fractal dimension is utilized as a parameter in a fitness function. The results have shown that the proposed approach yielded very good fit for the observation data. The hypothesis about fractal character of the wind speed is positively verified.

Fuel cell technology

13/02445 Balancing wind energy and participating in electricity markets with a fuel cell population

Heinz, B. and Henkel, J. *Energy*, 2012, 48, (1), 188–195.

In this paper an integrated fuel cell/household model is developed in order to assess the capability of fuel cells to fulfil different tasks in the energy market. The dynamic properties of two stationary combined heat and power (CHP) fuel cell systems were determined experimentally and serve as a basis for the development of the model. Based on this model, the possible contributions of fuel cell systems to a decentralized supply structure are investigated. The results show that if more than 24 households with a fuel cell are interconnected, the fuel cells are able to cover 99.6% of the entire household electricity demand. Additionally, German wind energy feed-in compensation is modelled. Here the results show that the influence on the wind power feed-in is limited because only for a small number of days with wind power production above median level the virtual fuel cell power plant can compensate the wind power feed-in by reducing its output. Thirdly, the potential use of excess electrical capacity from larger fuel cell populations sold at an energy exchange is examined. Here the simulation results show that trading can generate contribution margins of between 140 and 200 Euros per year. Consequently, fuel cells could be significant at the energy exchange, if fuel cell investment costs decreased in the future.

13/02446 Characterization of mixed-culture biofilms established in microbial fuel cells

Yang, S. *et al. Biomass and Bioenergy*, 2012, 46, 531–537.

For the successful operation of a microbial fuel cell, it is important to characterize the biofilm on the anode. The behaviour of MFCs during initial biofilm growth and characterization of anodic biofilm were studied using two-chamber MFCs with activated sludge as inoculum. After three times' replacement of the anodic growth medium, the biofilms were well developed, and a maximum closed circuit potential of 0.41 and 0.37 V (1000 Ω resistor) was achieved using acetate and glucose, respectively. Electron microscopy revealed that there were rod-shaped cells 0.2–0.3 µm wide by 1.5–2.5 µm long in the anode biofilm in the acetate-fed MFC, and these cells were mainly arranged by monolayer. The biofilm in the glucose-fed MFC was made of cocci-shaped cells in chains and a thick matrix. Both using acetate and glucose, the anodic bacterial communities were different than those of the activated sludge. Cyclic voltammograms suggested that extracellular electron transfer in these MFCs was accomplished mainly by the biofilms on the anode and not by bacteria-produced mediators.

13/02447 Combined heat, power and hydrogen production optimal planning of fuel cell power plants in distribution networks

Niknam, T. *et al. Energy Conversion and Management*, 2013, 66, 11–25.

Recently, due to technology improvements and governmental incentives for using the green energies, fuel cell power plants (FCPPs) seem to be a promising approach for electricity generation. FCPPs, as distributed generation (DG) units, can be considered as combined sources of heat, power, and hydrogen (CHPH). CHPH operation of FCPPs improves system efficiency because of produced hydrogen which can be stored for future use of FCPPs or can be sold for profit. Using $2m+1$ point estimate method, a probabilistic load flow approach is employed to model the uncertainties in electrical and thermal load demands, pressure of input oxygen and hydrogen importing to FCPPs, and temperature of FCPPs. Minimizing the operation costs of electrical energy generated by distribution substation and FCPPs, minimizing the voltage deviation, and minimizing total emissions produced by distribution substations and FCPPs are selected as objective functions. This paper just considers the placement of CHPH FCPPs without assuming the devices investment cost. A powerful optimization technique, θ-self adaptive gravitational search algorithm (θ-SAGSA), is proposed to achieve the optimal places for FCPPs and daily optimal active powers of distribution substation and FCPPs. For solving the proposed multi-objective problem, this paper utilizes the Pareto optimality idea to obtain a set of solutions in the multi-objective problem instead of a sole solution. The proposed method effectiveness is validated on a 69-bus distribution system.

13/02448 Design and analysis of a proton exchange membrane fuel cells (PEMFC)

Pandiyan, S. *et al. Renewable Energy*, 2013, 49, 161–165.

Flow distribution of both fuel and oxidant from the port to the individual cells critically control the performance of a proton exchange membrane fuel cells stack in combination. The low voltage generated in a fuel cell is compounded to usable value by stacking of cells. Under ideal conditions, a fuel cell stack performance is simply the sum of the performance of individual cells. However, this linear correlation is not achieved in practice. This is due to many reasons including poor distribution of reactants among different cells of the stack. Due to this flow mal-distribution, if the highest flow rate is adjusted at design value, other cells starve for fuel. Whereas, if the lowest flow rate is adjusted at the design value, other cells waste away the fuel. Hence, there is need to have accurate study of flow mal-distribution in a fuel cell and take remedial measures to reduce loss of output due to this flow deficiency. This paper simulates the distribution of fluids by analytical approach utilizing flow channelling model of a manifold to increase the power output of the fuel cell stack.

13/02449 Effect of cathode types on long-term performance and anode bacterial communities in microbial fuel cells

Zhang, G. *et al. Bioresource Technology*, 2012, 118, 249–256.

Effects of cathode types on the long-term stability of microbial fuel cell (MFC) and the anodic microbial communities were studied using $K_3Fe(CN)_6$ catholyte (R1), air cathode (R2) and biocathode (R3) over a testing time of 400 d. After 400 d of testing, the maximum power densities (P_{max}) of R1 and R2 decreased by 44% and 37%, and the Coulombic efficiencies (CEs) decreased 8.4% (R1) and 2.0% (R2), respectively, using the performances on 10 d as the comparison basis. Conversely, the P_{max} and CE of R3 increased by 68.2% and 116.8%, respectively. The non-ohmic resistances (R_{no}) in all tests were the principal contributors of cell internal resistances. Phylogenetic analyses revealed that the microbial communities on anodic surface varied with cathode types and operational history.

13/02450 Electricity generation using eight amino acids by air–cathode microbial fuel cells

Yang, Q. *et al. Fuel*, 2012, 102, 478–482.

Eight kinds of amino acids including L-serine (Ser), L-asparagine (Asn), L-aspartic acid (Asp), L-glutamicacid (Glu), DL-alanine (Ala), L-lysine (Lys), L-histidine (His) and L-arginine (Arg) are tested as substrates of single-chambered air–cathode microbial fuel cells (MFCs) with domestic wastewater as inoculation. Their total organic carbon (TOC) concentrations in solution are standardized as 720 mg L^{-1}. Ser produces the highest power density of 768 mW m^{-2} and Ala produces the lowest of 556 mW m^{-2}. The Coulombic efficiencies (CEs) vary from 13 ± 3% (obtained with Arg) to 30 ± 1% (obtained with Ala). The removal efficiencies of total nitrogen (TN) are from 55 ± 5% (Asn) to 94 ± 4% (Asp), which may be associated with CEs. Maximum voltage outputs and TOC concentrations of the substrates appear to satisfy the empirical Monod-type equation when the external resistance is 150 Ω. The performances of MFCs are considered to relate to the molecular weights and structures of eight amino acids.

13/02451 Fuel cell based micro-combined heat and power under different policy frameworks – an economic analysis

Pade, L.-L. and Schröder, S. T. *Energy Conversion and Management*, 2013, 66, 295–303.

The residential fuel cell technology faces a list of challenges, of which some are linked to the technology through the need of cost decreases and reliability improvements. Others are linked to the political stage, where the necessary support schemes have to be in place in combination with clear political objectives on the design of the future energy system. This article takes the point of departure in the existing support schemes, most common ownership structures, energy prices, electricity demand and heating demand in Denmark, France and Portugal. For the three countries, the authors analyse different constellations of operational strategies, ownership structures and promotion schemes and assess the necessary support levels for residential fuel cells under these constellations. It was found that the necessary support levels are not excessively high compared to the initial support levels, e.g. photovoltaic systems in Germany. Especially net metering in Denmark and price premiums for fuel cells functioning as a virtual power plant in France and Portugal seems promising. The annual number of operation hours depends strongly on the operational scheme. For thermal-led units, cold start and modulation capacity plays a certain role, whereas the fuel cell generates virtually permanently if it is part of a virtual power plant.

13/02452 Fuel flexibility: a key challenge for SOFC technology

Lo Faro, M. *et al. Fuel*, 2012, 102, 554–559.

This study deals with an investigation of the direct oxidation of organic fuels with different molecular weights in solid oxide fuel cells (SOFCs). It aims to demonstrate that the final products of the oxidation process are essentially CO_2 and water with a very low amount of secondary products. An anodic catalyst formulation characterized by mixed electronic–ionic conductivity (MIEC) in combination with ceria electrolyte was used for this purpose. The anodic catalyst consisted of a composite Ni-modified perovskite mixed with $Ce_{0.9}Gd_{0.1}O_2$. It provided reasonable fuel flexibility in SOFCs. To get insight into the reaction mechanism, the same anode formulation was investigated in an *ex situ* autothermal reforming test. The performances achieved with the direct utilization of both gaseous and liquid fuels appear promising for SOFC applications in remote and micro-distributed energy generation as well as for portable power sources. The anode layer demonstrated stable performance with very low amount of carbon deposition during more than 130 h testing under a direct utilization mode of dry organic fuels.

13/02453 Full and part load exergetic analysis of a hybrid micro gas turbine fuel cell system based on existing components

Bakalis, D. P. and Stamatis, A. G. *Energy Conversion and Management*, 2012, 64, 213–221.

The paper deals with the examination of a hybrid system consisting of a pre-commercially available high temperature solid oxide fuel cell and an existing recuperated microturbine. The irreversibilities and thermodynamic inefficiencies of the system are evaluated after examining the full and partial load exergetic performance and estimating the amount of exergy destruction and the efficiency of each hybrid system component. At full load operation the system achieves an exergetic efficiency of 59.8%, which increases during the partial load operation, as a variable speed control method is utilized. Furthermore, the effects of the various performance parameters such as fuel cell stack temperature and fuel utilization factor are assessed. The results showed that the components in which chemical reactions occur have the higher exergy destruction rates. The exergetic performance of the system is affected significantly by the stack temperature. Based on the exergetic analysis, suggestions are given for reducing the overall system irreversibility. Finally, the environmental impact of the operation of the hybrid system is evaluated and compared with a similarly rated conventional gas turbine plant. From the comparison it is apparent that the hybrid system obtains nearly double exergetic efficiency and about half the amount of greenhouse gas emissions compared with the conventional plant.

13/02454 Maximising electricity production by controlling the biofilm specific growth rate in microbial fuel cells

Ledezma, P. *et al. Bioresource Technology*, 2012, 118, 615–618.

The aim of this work is to study the relationship between growth rate and electricity production in perfusion-electrode microbial fuel cells (MFCs), across a wide range of flow rates by co-measurement of electrical output and changes in population numbers by viable counts and optical density. The experiments hereby presented demonstrate, for the first time to the authors' knowledge, that the anodic biofilm specific growth rate can be determined and controlled in common with other loose matrix perfusion systems. Feeding with nutrient-limiting conditions at a critical flow rate ($50.8\,mL\,h^{-1}$) resulted in the first experimental determination of maximum specific growth rate μ_{max} ($19.8\,day^{-1}$) for *Shewanella* spp. MFC biofilms, which is considerably higher than those predicted or assumed via mathematical modelling. It is also shown that, under carbon-energy limiting conditions there is a strong direct relationship between growth rate and electrical power output, with μ_{max} coinciding with maximum electrical power production.

13/02455 Mixing effect of biometric flow channel in microbial fuel cells

Qi, Z.-q. *et al. Applied Energy*, 2012, 100, 106–111.

Microbial fuel cell (MFC) technology can utilize microbiology to metabolize organic substance and transform the chemical energy into electrical energy, which can be widely applied to purify the environment and develop new energy. Now, a novel method of biometric mixer and biometric flow channel in MFC rarely utilized previously would be applied and investigated. Two parts of experiment related to biometric channel and biometric mixer experiment will be investigated respectively. Compared with common continuous MFC, the maximum power density of MFC with biometric channel can reach $91.81\,mW/m^3$, and the stable discharging voltage can retrain at 0.5 mV. Based on experiment, the biometric mixer is added and the effect is discussed. It is found that the average mixing efficiency of nutrient source and bacteria liquid reaches 98%, and the maximum power density reaches $118.34\,mW/m^3$, 28.9% higher than that of MFC without mixer. These results show that the biometric channel and biometric mixer can be useful to enhance the power performance and could be widely applied to all kinds of MFCs in the future.

13/02456 Operation of a solid oxide fuel cell on a reformed FAME mixture

Siefert, N. S. *et al. Biomass and Bioenergy*, 2012, 47, 362–371.

The operation of a solid oxide fuel cell (SOFC) using a reformed fatty acid methyl ester (FAME) mixture, a biodiesel-like fuel, has been successfully demonstrated. This project had two main aspects: (1) determining the fuel reforming activity of a pyrochlore catalyst deposited onto a monolith; and (2) operating a SOFC on reformed fuel gas. Prior to integrated testing, parametric reforming studies of the FAME mixture were conducted using both $Rh/\gamma\text{-}Al_2O_3$ and Rh-substituted pyrochlore catalyst powders to determine the operating conditions to maximize syngas selectivity. Using the same pyrochlore catalyst as in the parametric studies, a monolith reformer converted $0.5\,cm^3\,min^{-1}$ of the FAME mixture into mostly hydrogen and carbon monoxide (syngas). The syngas generated in the reformer was sent to an anode supported SOFC (H.C. Starck Ceramics GmbH & Co.) The SOFC operated on 98% H_2/2% H_2O for baseline testing before and after switching to the reformed FAME mixture for 100 h of operation. The results presented here demonstrate that FAME mixture can be successfully reformed to power a SOFC, making them a viable fuel for a SOFC-based auxiliary power unit that is both greenhouse gas neutral and renewable.

13/02457 Stacks with TiN/titanium as the bipolar plate for PEMFCs

Ren, R. *et al. Energy*, 2012, 48, (1), 577–581.

Proton exchange membrane fuel cell (PEMFC) is a potential alternative for the internal combustion engine. But many problems, such as metallic bipolar plate instead of graphite bipolar plate to decrease the cost, should be solved before its application. Based on the previous results that single cell with TiN/Ti as bipolar plates shows high performance and enough long-time durability, the progress on the stacks with TiN/Ti as bipolar plates is reported in this manuscript. Until now few reports have focused on stacks because of the complicated processing technique, especially for that with TiN/Ti as bipolar plate. The flow field in the plate is punched from titanium deformation, and two plates are welded by laser welding to form one piece of bipolar plate. The adopted processing techniques for stacks with TiN/Ti as bipolar plate exhibit advantage and feasibility in industry. The power density by weight for the stack is as high as $1353\,W\,kg^{-1}$, although it still has space to be improved. Next work should be focused on the design of flow channel parameters and flow field type based on plastic deformation of metal materials.

15 ENVIRONMENT

Pollution, health protection, applications

13/02458 A comprehensive analysis of the impact of occupancy parameters in energy simulation of office buildings

Azar, E. and Menassa, C. C. *Energy and Buildings*, 2012, 55, 841–853.

The commercial building sector has become the focus of many governmental energy reduction initiatives to achieve more sustainable development. Reducing building energy use starts by improving the design of buildings. To this end, energy modelling and simulation tools are used during the design phase to predict energy use and help designers choose and size the different building systems. Large discrepancies are however being observed between predicted and actual building energy performances. In order to determine the sources of errors and improve these predictions, the sensitivity of energy models to different input parameters needs to be evaluated. Studies in literature have extensively evaluated the sensitivity of models to the buildings' technical design parameters. However, none considered the parameters related to the energy consumption behaviour of occupants, leaving their impact on energy modelling unknown. This paper presents a comprehensive sensitivity analysis study performed on the occupancy behavioural parameters of typical office buildings of different size and in different weather zones. Significant sensitivity levels were observed, varying according to both building size and weather conditions. The highest sensitivity was obtained when varying the 'heating temperature set point' parameter in small-size buildings located in US weather zone 2 dry.

13/02459 Air pollution and daily mortality: a new approach to an old problem

Lipfert, F. W. and Murray, C. J. *Atmospheric Environment*, 2012, 55, 467–474.

Many time-series studies find associations between acute health effects and ambient air quality under current conditions. However, few such studies link mortality with morbidity to provide rational bases for improving public health. This paper describes a research project that developed and validated a new modelling approach directly addressing changes in life expectancies and the prematurity of deaths associated with transient changes in air quality. The authors used state-space modelling and Kalman filtering of elderly Philadelphia mortality counts from 1974 to 1988 to estimate the size of the population at highest risk of imminent death. This subpopulation appears stable over time but is sensitive to season and to environmental factors: ambient temperature, ozone, and total suspended particulate matter (TSP), as an index of airborne particles in this demonstration of methodology. This population at extreme risk averages fewer than 0.1% of the elderly. By considering successively longer lags or moving averages of TSP, it was found that cumulative short-term effects on entry to the at-risk pool tend to level off and decrease as periods of exposure longer than a few days are considered. These estimated environmental effects on the elderly are consistent with previous analyses using conventional time-series methods. However, this new model suggests that such environmentally linked deaths comprise only about half of the subjects whose frailty is associated with environmental factors. The average life expectancy of persons in the at-risk pool is estimated to be 5–7 days, which may be reduced by less than one day by environmental effects. These results suggest that exposures leading up to severe acute frailty and subsequent risk of imminent death may be more important from a public health perspective than those directly associated with subsequent mortality.

13/02460 Assessing mental workload and situation awareness in the evaluation of computerized procedures in the main control room

Yang, C.-W. *et al. Nuclear Engineering and Design*, 2012, 250, 713–719.

Computerized procedures (CPs) developed in nuclear power plant instrumentation and control (I&C) systems may include normal operating procedures, abnormal operating procedures, alarm response procedures, surveillance test procedures and/or emergency operating procedures. While there are many ways to evaluate the design of these computerized procedures, the user's mental workload and situation awareness (SA) are particularly important considerations in the supervisory control of safety-critical systems. Users' mental workload and situation awareness may be influenced by human factor issues relating to computerized procedures, e.g. level of automation, dealing with (partially) unavailable I&C, switching to back-up system (e.g. paper-based procedures). Some of the positive impacts of CPs on operator performance include the following: tasks can be performed more quickly; overall workload can be reduced; cognitive workload can be minimized; fewer errors may be made in transitioning through or between procedures. However, various challenges have also been identified with CP systems. These should be addressed in the design and implementation of CPs where they are applicable. For example, narrower 'field of view' provided by CP systems than with paper-based procedures could reduce crew communications and crewmember awareness of the status and progress through the procedure. Based on a human factors experiment in which each participant monitored and controlled multiple simulated reactors, this study applied the NASA-TLX instrument for assessing mental workload. For the assessment of situation awareness (SA), the present research used the situational awareness rating technique. In support of summarizing the results of user interface evaluation along multiple dimensions (e.g. workload, SA), advantages are proposed for the CPs compared to the paper-based procedures.

13/02461 Behaviour, attitudes and opinion of large enterprise employees with regard to their energy usage habits and adoption of energy saving measures

Nisiforou, O. A. *et al. Energy and Buildings*, 2012, 55, 299–311.

Occupants' behaviour is one of the important aspects in diminishing energy waste. It is imperative that working environments should provide comfort to occupants and at the same time, they should also be in line with energy saving practices. The present study aims in investigating energy usage habits of a large enterprise employees in Cyprus, in evaluating their perception on consumption on various energy saving measures and finally, in statistically analysing their behaviour, attitudes and opinion on energy usage and energy saving measures. Furthermore, the decisions taken by the upper management and its role on energy management is presented and analysed. To achieve the above aims, a detailed questionnaire was designed. Results showed that the majority of employees acknowledge that there is energy waste and that, in theory, they would be open to energy saving measures. They tend to believe that a complete energy management system must be applied, but when they were asked specifically about temperature control, they prefer individual control. Thus, they are not willing to sacrifice their own personal satisfaction for these measures. Furthermore, statistical analysis showed that employees sharing an office and have either less than 10 or more than 20 years of employment are the most dissatisfied about room temperature and thus, they would pose a difficulty in accepting energy saving measures. Finally, the upper management lacks in the promotion of energy saving measures, and this also contributes negatively in the employees' behaviour.

13/02462 Biofuels and employment effects: implications for socio-economic development in Thailand

Silalertruksa, T. *et al. Biomass and Bioenergy*, 2012, 46, 409–418.

The study assesses the impacts of the biofuels production to the socio-economic development in Thailand. The four kinds of biofuels considered in the analyses are ethanol from cassava, molasses and sugarcane ethanol as well as palm biodiesel. The key elements of socio-economic development including employment generation, economic effects on GDP and trade balance are investigated based on a combination of process and input–output analysis. The results show that producing ethanol and biodiesel require about 17–20 and 10 times more workers than gasoline and diesel as per energy content, respectively. Direct employment in agriculture contributes to more than 90% of total employment. Nevertheless, there are the significant differences in the characteristics of employment in the agriculture and biofuel processing sectors. The overall impacts of ethanol production in Thailand in year 2022 are the employment generation of around 238,700–382,400 person-years, $150 million additional gross domestic product, imported goods worth $1583 million but $2547 million of imports would be saved if compared to petroleum fuels. The other socio-economic aspects such as agricultural improvement and rural development due to biofuels policy in Thailand and some policy measures that need to be urgently promoted are also discussed in the study.

13/02463 Bioreactor leaching of uranium from a low grade Indian silicate ore

Abhilash, and Pandey, B. D. *Biochemical Engineering Journal*, 2013, 71, 111–117.

Bio-leaching studies were carried out in a 2 L bioreactor BIOSTAT-B® equipped with a PLC-based controller at 20–40% (w/v) pulp density using enriched culture of *A. ferrooxidans* for Turamdih uranium ore (Jharkhand, India). With the enriched culture of *A. ferrooxidans* adapted on Fe(II) at pH 2.0, 35 °C and 20% (w/v) pulp density, a 98.3% uranium recovery was recorded in 14 days. The leaching of uranium in the bioreactor improved the dissolution rate by reducing the time from 40 days in shake flask as per earlier studies to 14 days. While investigating the importance of biogenic Fe(III) in the bioleaching process a maximum recovery of 84.7% U_3O_8 was observed at pH 2.0 and 20% (w/v) pulp density in 10 h as compared to the uranium leaching of 38.3% in the control experiments. On raising the pulp density to 30%, uranium bio-recovery increased to 87.6% in 10 h at pH 2.0 with $<76\,\mu m$ size material. This showed a distinct advantage because of better mixing of slurry in the bioreactor with auto-controlled conditions that improved the kinetics.

13/02464 Characteristics of large-magnitude microseismic events recorded during and after stimulation of a geothermal reservoir at Basel, Switzerland

Mukuhira, Y. *et al. Geothermics*, 2013, 45, 1–17.

Induced seismicity with large events occurred during and after a hydraulic stimulation at Basel, Switzerland, in 2006. This paper describes a study of the characteristics of the large events (those of moment magnitude >2.0) in order to understand their origin. The large events during the stimulation and just after bleeding off had hypocentres within the seismic cloud while the large events that occurred several weeks after shut-in were located outside of the seismic cloud. No evidence was found that either local stress concentration or increased pore pressure caused the increase of event magnitudes as no shear slip with extremely high stress drop, or a significant correlation between pore pressure and large event magnitude were identified. The integrated analysis of the fault plane solution and rock failure mechanism showed unbalanced seismic activity and seismic energy release in the pre-existing fracture system. From these observations it was concluded that the large events did not originate from the rupture of rigid asperities triggered by increased pore pressure. The observations suggest instead that critical changes of the stress state or coefficient of friction on fracture planes during stimulation triggered the unstable shear slip of large events. It was also concluded that the characteristics of the large events are dependent on their occurrence times and hypocentral locations.

13/02465 Clean energy that safeguards ecosystems and livelihoods: integrated assessments to unleash full sustainable potential for renewable energy

Athanas, A. K. *et al. Renewable Energy*, 2013, 49, 25–28.

In promoting renewable energy options, the environmental problem of greenhouse gas emissions should not be replaced with other environmental problems. Large-scale renewable infrastructure projects in particular – from offshore wind farms to concentrated solar towers to hydropower installations – need to be accompanied by adequate environmental and social impact assessments. For policies, plans and programmes around renewable energy investments, strategic environmental assessments should be applied. Such assessments will increasingly need to consider the changing nature of supporting ecosystem services and the need for climate adaptation. Financing institutions should promote appropriate safeguards, supported by capacity building activities from international organizations, including IRENA, in order to unleash the full sustainable potential of renewable energy options. This paper explores the experiences of applying impact assessment tools and processes to renewable investments and highlights some of the key aspects which should be taken into consideration when pursuing a renewable energy future.

13/02466 Consumers satisfaction in the energy sector in Kenya

Mutua, J. *et al. Energy Policy*, 2012, 48, 702–710.

This paper analyses consumer satisfaction in the energy sector in Kenya to assess the quality and level of service delivery. By use of the European consumer satisfaction index, the paper estimates consumer satisfaction in biomass, petroleum, electricity and renewable energy subsectors. The findings are that consumer satisfaction is highest in the renewable energy sub-sector at 74.7% followed by petroleum at 62.8%. The electricity sub-sector has the lowest consumer satisfaction of 53.06%. Further, it is found that the image of renewable energy providers is also the highest at 72.5% followed by that of petroleum companies at 63.1%. In the electricity sub-sector, perceived value scored the highest at 64.2%. The paper concludes that image of a service provider, loyalty of consumers, consumer expectations, perceived value, perceived quality and the way complains are handled are very important factors that determine consumer satisfaction levels. It is recommended that for monitoring and evaluation purposes in the performance of the energy sector, the Energy Regulatory Commission could use the consumer satisfaction index level to evaluate whether the regulatory policies and their implementation are bearing fruit where a high index would be associated with good performance and vice versa.

13/02467 Cost-effectiveness of GHG emission reduction measures and energy recovery from municipal waste in Croatia

Rolph Schneider, D. *et al. Energy*, 2012, 48, (1), 203–211.

Many of the modern practices in waste management at the same time represent means of reduction of greenhouse gas (GHG) emissions. The main focus in this paper is given to the measures for recovering energy from municipal solid waste (MSW): utilization of landfill gas for electricity production, utilization of refuse derived fuel (RDF) in cement industry, Thermal treatment (incineration) of MSW, Mechanical-biological treatment, and to one measure without energy recovery – landfill gas flaring, for all of which it was found that could generate substantial GHG emission savings. The economic side of the implementation of these measures, considering the GHG emission reduction, is analysed in order to determine the priority between them. With respect to the cost-effectiveness, marginal costs (expressed as € per ton of reduced or avoided CO_2eq) are calculated for all the measures. It was determined that around 1 million tons of CO_2 can be avoided in 2020, which is 2.7% of projected GHG emissions in Croatia, while the energy that could be recovered from waste is 8.3 PJ in 2020, which represents about 3% of the total final energy consumption in 2008. The measures utilization of landfill gas for electricity production and landfill gas flaring showed the greatest economic benefit.

13/02468 Decision support systems for power plants impact on the living standard

Chatzimouratidis, A. I. and Pilavachi, P. A. *Energy Conversion and Management*, 2012, 64, 182–198.

In developed countries, the quality of life is of first priority and an overall assessment of power plant impact on the living standard requires a multicriteria analysis of both positive and negative factors incorporating uncertainty in criteria performance and probability assessment of weighting factors. This study incorporates PROMETHEE II to assess 10 major types of power plant under 12 criteria, 13 fixed and infinite customized probability assessed weight set scenarios. The power plants considered are coal/lignite, oil, natural gas turbine, natural gas combined cycle, nuclear, hydro, wind, photovoltaic, biomass and geothermal. Geothermal, wind and photovoltaic power plants are excellent choices in most of the cases and biomass and hydro should also be preferred to nuclear and fossil fuel. Among nuclear and fossil fuel the choice is based on the specific parameters of each case examined while natural gas technologies have specific advantages. The motivation of this study was to provide a tool for the decision-maker to evaluate all major types of power plant incorporating multicriteria and customized probability assessment of weighting factors.

13/02469 Effects of thermal comfort and adaptation on park attendance regarding different shading levels and activity types

Lin, T.-P. *et al. Building and Environment*, 2012, 59, 599–611.

Outdoor thermal environments influence thermal adaptation, thereby affecting the utilization of space. To determine the effects of thermal comfort and adaptation on attendance regarding different shading levels and activity types, this study conducted field investigations at a public park located in southern Taiwan, using micrometeorological measurements, estimations of park attendance, and questionnaire surveys on thermal comfort. The results indicate that participants' acceptable range of thermal comfort leads to substantial changes in overall park attendance during different seasons, whereas characteristics of thermal adaptations influence the individual differences of utilization in various ways within diverse spaces. In addition, this study reveals that in unshaded areas within parks, the number of visitors increases following rising thermal conditions during cool seasons, whereas the number of visitors decreases during hot seasons. However, the number of visitors to shaded areas increases with rising thermal conditions in both cool and hot seasons. Because of the possibility and effectiveness of personal behaviour adjustments (e.g. decreases in the amount of clothing worn, the wearing of hats, or carrying of an umbrella) in decreasing thermal discomfort, people choose to seek adjustments in external environments. That is, they move from unshaded to shaded areas to relieve their perception of thermal discomfort. The results of this study reveal the importance of shading facilities within parks in the hot climate zone of Taiwan, and can be used as references in future park designs.

13/02470 Emission consequences of introducing bio ethanol as a fuel for gasoline cars

Winther, M. *et al. Atmospheric Environment*, 2012, 55, 144–153.

This article describes the direct vehicle emission impact of the future use of bioethanol as a fuel for gasoline cars in Denmark arising from the vehicle specific fuel consumption and emission differences between neat gasoline (E0) and E5/E85 gasoline–ethanol fuel blends derived from emission tests using primarily the European NEDC and ARTEMIS driving cycles. The E0–E5 test vehicles (nine cars) represent today's gasoline car traffic well where most of the driving is being made with cars certified as Euro 3+. The FFV test cars (25 cars) are all certified according to the Euro 4 emission standard introduced in Europe from the mid-2000s. This matches well with the propagation of the FFV technology in Europe. For vehicles using E5 rather than E0, the average fuel consumption and emission differences are small. For CO, VOC and NO_x the derived average differences are 0.5%, –5% and 7%, respectively. For FFVs using E85 rather than E5, the emission differences become even smaller for VOC and NO_x, but greater for CO. The derived average emission differences are in this case 18%, –1% and 5% for CO, VOC and NO_x, respectively. In both comparative cases there is a large variation in the emission difference values calculated for the individual cars. The large standard deviations introduce some uncertainties in the final averages computed for each emission component. The vehicle based emissions are made up for two fossil fuel baseline scenarios (FS), characterized by high and low traffic growth rates. For each FS, two biofuel scenarios (BS1, BS2) are presented. BS1 reaches the Danish policy targets (10% biofuel share in 2020). BS2 is more ambitious (25% in 2030). By definition the biofuel part of the combusted fuel is CO_2 neutral and the maximum CO_2 emission difference between FS and BS2 becomes 27% in 2030. As predicted by the vehicle specific emission differences the calculated emission impacts of using bioethanol are small for NO_x, VOC and CO. Instead, for FS, BS1 and BS2 large emission reductions are due to the gradually cleaner new sold gasoline cars and the decline in total mileage until the mid-2010s.

13/02471 Energy and quality of life

Pasten, C. and Santamarina, J. C. *Energy Policy*, 2012, 49, 468–476.

Energy is required to sustain life. A human-centred analysis of the global energy situation is conducted in terms of quality of life-related variables that are affected, but not directly determined, by energy consumption. Data since 1980 show a continuous global increase in both energy consumption and quality of life, and lower population growth in countries with higher quality of life. Based on these trends, this study advances non-linear energy consumption predictions and identify various plausible scenarios to optimally steer future energy demands, in order to maximize quality of life. The scenarios consider the coupling between energy consumption rate per capita, quality of life, population growth, social inequality, and governments' energy-for-life efficiency. The results show the energy cost of increasing quality of life in the developing world, energy savings that can be realized by limiting overconsumption without impacting quality of life, and the role of governments on increasing energy-for-life efficiency and reducing social inequality.

13/02472 Energy-related climate change mitigation in Brazil: potential, abatement costs and associated policies

Borba, B. S. M. C. *et al. Energy Policy*, 2012, 49, 430–441.

This paper estimates the potential for energy-related greenhouse gas emission (GHG) reductions in Brazil, their abatement costs and proposes a number of policies to achieve these reductions. The Brazilian energy system is very peculiar as renewable energy accounts for some 45% of total primary energy and 85% of electricity production. The following sectors are covered in this paper: industry, transports and petroleum sector. Compared to a business-as-usual reference scenario, results show a potential to reduce future energy-related GHG emissions by 27% in 2030. However, in spite of that, the mitigation potential identified here is not large enough, in absolute terms, to reduce energy-related GHG emissions below the current level in Brazil by 2030.

13/02473 Human reliability analysis data obtainment through fuzzy logic in nuclear plants

do Nascimento, C. S. and de Mesquita, R. N. *Nuclear Engineering and Design*, 2012, 250, 671–677.

Human error has been recognized as an important factor for many industrial and nuclear accidents occurrence. Human error data is scarcely available for different reasons among which, lapses in historical database registry methodology is an important one. Human reliability analysis (HRA) is an usual tool employed to estimate the probability that an operator will reasonably perform a system required task in required time without degrading the system. This meta-analysis requires specific human error probability estimates for most of its procedure. This work obtains human error probability (HEP) estimates from operator's actions in response to emergency situations hypothesis on research reactor IEA-R1 from IPEN, Brazil. Through this proposed methodology HRA should be able to be performed even with shortage of related human error statistical data. A performance shaping factors (PSFs) evaluation in order to classify and estimate their influence level onto the operator's actions and to determine their actual state over the plant was also done. Both HEP estimation and PSF evaluation were done based on expert judgment using interviews and questionnaires. Expert group was established based on selected IEA-R1 operators, and their evaluation were put into a knowledge representation system which used linguistic variables and group evaluation values that were obtained through fuzzy logic and fuzzy set theory. HEP obtained values show good agreement with literature published data corroborating the proposed methodology as a good alternative to be used on HRA.

13/02474 Influence of residents on energy use in 57 Swedish houses measured during four winter days

Hiller, C. *Energy and Buildings*, 2012, 54, 376–385.

The aim of this paper is to contribute to the knowledge about energy use in residential buildings. Field measurements were carried out in 57 electrically heated Swedish single-family houses, where the total energy use (i.e. electricity use for space heating, household electricity and electricity use for hot water production), indoor temperatures and water use were recorded during four winter days. Some of the findings were that differences for households' total energy use of similar houses were large. The characteristics of load curves clearly differ between weekdays and weekend days. The water use differs greatly for the households. This paper is part of a larger project where time use diaries were used in order to further link the energy use to residents' every day energy related behaviours. To get a better understanding of the energy use within homes is a prerequisite to be able to both recognize the problems as well as the potentials of reaching energy goals of society, leading to a decreased impact on the environment from the building sector.

13/02475 Investigation of human body skin temperatures as a bio-signal to indicate overall thermal sensations

Choi, J.-H. and Loftness, V. *Building and Environment*, 2012, 58, 258–269.

This study investigates the possibility of the use of human body skin temperature to assess thermal sensation, by studying skin temperatures from ten body segments and analysing the correlation between the physiological data: skin temperature and overall thermal sensation. Since the human body regulates skin temperature to balance the heat gain and heat loss, the use of skin temperature has significant potential as an index to the thermal sensation. Therefore, this research has relied on experiments using human subjects in an environmental chamber to investigate and determine how skin temperatures change, depending on the ambient thermal conditions, and to identify which data type and body segment generate the most significant physiological information that will represent the overall thermal sensation. For this study, the experiments were conducted with 26 volunteers in an experimental chamber for about 2 h each, while the indoor temperature was changed from 20 to 30 °C. Results of this study revealed that skin temperature change rates (gradients) were more consistent with the thermal comfort condition than with the actual levels of skin temperatures of participants, and that the measured skin temperatures at their wrists provided more interpretable data than that of any other body segments. Therefore, the research findings have shown the potential of skin temperature as a thermal sensation index to reliably represent an individual's thermal sensation in a thermally uniformed environment.

13/02476 Is economic growth good or bad for the environment? Empirical evidence from Korea

Baek, J. and Kim, H. S. *Energy Economics*, 2013, 36, 744–749.

The effects of economic growth on the environment in Korea, for a given level of energy consumption, and fossil fuels and nuclear energy in electricity production, are examined in a dynamic cointegration framework. To that end, the autoregressive distributed lag approach is used. Empirical evidence was found supporting the existence of the environmental Kuznets curve hypothesis for Korea; that is, economic growth indeed plays a favourable role in influencing environmental outcomes. It is also found that, in both the short and long run, nuclear energy has a beneficial effect on environmental quality, whereas fossil fuels in electricity production and energy consumption have a detrimental effect on the environment.

13/02477 Man-portable personal cooling garment based on vacuum desiccant cooling

Yang, Y. *et al. Applied Thermal Engineering*, 2012, 47, 18–24.

A human portable personal cooling garment based on the concept of vacuum desiccant cooling (VDC) was developed. It was demonstrated with cooling pads that a cooling capacity of 373.1 W/m^2 could be achieved in an ambient environment of 37 °C. Tests with human subjects wearing prototype cooling garments consisting of 12 VDC pads with an overall weight of 3.4 kg covering 0.4 m^2 body surface indicate that the garment could maintain a core temperature substantially lower than the control when the workload was walking on a treadmill of 2% inclination at 3 mph. The exercise was carried out in an environment of 40 °C and 50% relative humidity (RH) for 60 min. Tests also showed that the VDC garment could effectively reduce the metabolic heat accumulation in body with subject wearing heavily insulated nuclear, biological and chemical (NBC) suit working in the heat and allow the participant to work safely for 60 min, almost doubling the safe working time of the same participant when he wore NBC suit only.

13/02478 Metal contamination and solid phase partitioning of metals in the stream and bottom sediments in a reservoir receiving mine drainage

Lee, P.-K. *et al. Applied Geochemistry*, 2013, 28, 80–90.

This study was conducted to assess the anthropogenic impact on metal concentrations in the bottom sediments of the Juam reservoir, Korea, and in stream sediments in its catchment, and to estimate the potential mobility of selected metals (Fe, Mn, Cu, Ni, Pb and Zn) using sequential extraction. A comparison of the metal concentrations in the stream sediments with mean background values in sediments collected from first- or second-order creeks shows that Pb, Cu and Ni are the most affected by anthropogenic inputs. The ^{206}Pb/^{207}Pb ratios of the bottom and core sediments (means: 1.2320 ± 0.0502 and 1.2212 ± 0.0040, respectively) suggest that Pb contamination is mainly due to the waste discharge of abandoned coal and metal mines rather than industrial and airborne sources. Considering the proportion of metals bound to the exchangeable, carbonate and reducible fractions, the comparative mobility of metals is suggested to decrease in the order $\mathrm{Mn} > \mathrm{Pb} > \mathrm{Zn} > \mathrm{Ni} > \mathrm{Fe} \gg \mathrm{Cu}$.

13/02479 Mitigation of global warming through renewable biomass

Dhillon, R. S. and von Wuehlisch, G. *Biomass and Bioenergy*, 2013, 48, 75–89.

Rising level of atmospheric CO$_2$ and consequent global warming is evident. Global surface temperatures have already increased by 0.8 °C over the twentieth century and are projected to increase by 1.4–5.8 °C during the twenty-first century. Global warming will continue until atmospheric concentrations of the major greenhouse gases are stabilized. Among them, CO$_2$ is mainly responsible and is expected to account for about 60% of the warming over the next century. This study reviews the advances on the causes and consequences of global climate change and its impact on nature and society. Renewable biomass has tremendous potential to mitigate global warming. Renewable biomass is expected to play a multifunctional role including food production, source of energy and fodder, biodiversity conservation, yield of goods and services to the society as well as mitigation of the impact of climate change. The review highlights the different management and research strategies in forestry, agriculture, agroforestry and grasslands to mitigate the global warming.

13/02480 Occupants' window opening behaviour: a literature review of factors influencing occupant behaviour and models

Fabi, V. *et al. Building and Environment*, 2012, 58, 188–198.
Energy consumption in buildings is influenced by several factors related to the building properties and the building controls, some of them highly connected to the behaviour of their occupants. In this paper, a definition of items referring to occupant behaviour related to the building control systems is proposed, based on studies presented in literature and a general process leading to the effects on energy consumptions is identified. Existing studies on the topic of window opening behaviour are highlighted and a theoretical framework to deal with occupants' interactions with building controls, aimed at improving or maintaining the preferred indoor environmental conditions, is elaborated. This approach is used to look into the drivers for the actions taken by the occupants (windows opening and closing) and to investigate the existing models in literature of these actions for both residential and office buildings. The analysis of the literature highlights how a shared approach on identifying the driving forces for occupants' window opening and closing behaviour has not yet been reached. However, the reporting of variables found not to be drivers may reveal contradictions in the obtained results and may be a significant tool to help direct future research.

13/02481 Power without manpower: forecasting labour demand for Estonian energy sector

Meriküll, J. *et al. Energy Policy*, 2012, 49, 740–750.
As energy demand and prices continue to grow, oil shale might help mitigate the energy crisis – it can widely be found all over the world but so far has not been widely used. Estonia is unique in the world for producing a large majority of energy out of oil shale and has been set as an example in numerous papers covering oil shale deposits, technology, etc. This paper is the first to analyse oil shale energy related workforce and provides scenario forecasts of the labour demand for the Estonian energy sector in 2010–2020. The contribution of the paper is twofold. First, the paper provides a valuable insight into oil shale energy related workforce, enabling to take into consideration the educational needs in countries where oil shale industry might be set up. Second, methodology-wise, the paper relates labour demand and supply to different scenarios of energy production capacities. The results illustrate problems related to aging of the workforce in energy production. If the existing trends continue in educational attainment in Estonia, there will be a serious shortage of high-skilled engineering and manufacturing specialists. This method provides a simple yet reliable enough way to check for such problems early enough.

13/02482 Simulation of climate change impact on energy consumption in buildings, case study of Iran

Roshan, G. R. *et al. Energy Policy*, 2012, 49, 731–739.
The purpose of this research is to simulate the impact of climate changes on the need for energy consumption in household cooling and heating systems using degree-day index. To this end, general circulation model has been applied to identify future climate changes and simulate degree-day values. The research findings show an increase of energy consumption for cooling in households in 2075. Also, with warm seasons prolonging and cold seasons shrinking in a year, the need for the continuous supply of energy consumption for air cooling and ventilation increases.

13/02483 Size matters: house size and thermal efficiency as policy strategies to reduce net emissions of new developments

Clune, S. *et al. Energy Policy*, 2012, 48, 657–667.
Reducing carbon dioxide equivalent (CO_2-e) emissions from residential buildings through more stringent building codes has gained increasing international focus. Concurrently, Australian houses have steadily increased in size from 1984 to 2009. This paper estimates the capacity of building codes to reduce residential emissions and achieve progressive reduction targets in light of increasing house sizes. A Residential Emissions Calculator was developed to compare heating and cooling loads for 72 new Australian houses – based on star ratings, historic Australian house sizes by state, and international house sizes. The analysis illustrates that house size has significant impact on the capacity of residential building codes to reduce emissions, and informs three key results: (1) Victoria is forecast to dominate emissions from new houses in Australia, (2) the increase in house size from 2003 to 2009 in Victoria decreased the effectiveness of moving from five stars to six stars by 38%, (3) progressive CO_2-e reduction targets of 80% could be achieved by a variety of house size and star rating scenarios (with significant housing affordability impacts). The result posit building codes and house size as potent strategies to limit energy associated emissions and underlines the need to apply these strategies in tandem as part of integrated national emissions management policy.

13/02484 Sleep thermal comfort and the energy saving potential due to reduced indoor operative temperature during sleep

Leung, C. and Ge, H. *Building and Environment*, 2012, 59, 91–98.
The optimal human body thermal conditions for comfortable sleep differ significantly from the optimal body thermal conditions for being awake. With the body covering such as a blanket representing a higher insulation value than the typical indoor attire suggests that a significant indoor temperature reduction during sleep may be available. With known skin temperature and heat loss rate required for comfortable sleep, a numerical model was developed for a 50th percentile male to calculate the desired thermal environment for sleep. The results show that the thermal environment represented by the operative temperature of the room can be reduced to around 15 °C to maintain sleep thermal comfort. This is significantly less than the thermal environment required by the building codes and ASHRAE comfort standard, which suggests that the heating system output may be reduced, which translates to potential energy savings and improved quality of thermal environment for sleep thermal comfort. As a part of a field study, data collected from a radiant ceiling heated house show that the operative temperatures exceed the desired thermal environment conditions for comfortable sleep. A calculation on the peak heating day with the building characteristics was performed with reduced heating set points during sleep. It was found that up to 10% of the heating energy may be reduced. The eQuest energy simulations show that an approximately 2% saving in total space heating demand can be achieved for 1 °C set-point reduction during the 8 h nighttime.

13/02485 The measurement of the solar absorptance of the clothed human body – the case of Japanese, college-aged male subjects

Watanabe, S. *et al. Building and Environment*, 2012, 59, 492–500.
In an outdoor environment, thermal comfort is affected by various factors, in particular solar radiation. Quantifying the solar absorptance of a human body is necessary for accurately assessing outdoor thermal comfort. Numerous studies have measured the solar absorptance of skin and fabrics. However, these measurements do not represent the solar absorptance of clothed humans. This study intends to determine the average solar absorptance of the human body wearing a combination of specific black and white garments and measure the average solar absorptance of Japanese, college-aged male subjects wearing casual summer, autumn, and winter clothing. The solar absorptance of the entire clothed human body was derived from these measurements. The solar absorptance of a black shirt and black trousers combination was found to be 0.76. For the combination of a white shirt and white trousers, the minimum solar absorptance was 0.38. Furthermore, the average solar absorptances of 30 Japanese, college-aged male subjects wearing casual clothing in summer, autumn, and winter were 0.66, 0.69, and 0.77, respectively. In summer, the average solar absorptance of the subjects in casual clothing depended on the colour of tops. The average solar absorptances were suggested to be 0.76, 0.56 and 0.68 for subjects wearing black tops, white tops, and tops with Munsell values between 2 and 8, respectively.

13/02486 Thermal comfort conditions in sustainable buildings – results of a worldwide survey of users' perceptions

Baird, G. and Field, C. *Renewable Energy*, 2013, 49, 44–47.
The users' perceptions of thermal comfort in 36 sustainable commercial and institutional buildings in 11 countries have been investigated. This paper describes and analyses the users' overall perceptions of temperature and of air quality in both summer and winter, and in particular whether they found conditions hot or cold, stable or variable, still or draughty, dry or humid, fresh or stuffy, or odourless or smelly. The results from these analyses indicated a good degree of satisfaction with internal thermal comfort conditions overall. The temperatures and air quality factors of these buildings proved to be better, on average, than a set of more conventional buildings However, conditions were perceived to be on the cold side in winter and on the hot side in summer. This indicates that more attention must be given to these aspects of design and operation.

13/02487 Toxic elements mobility in coal and ashes of Figueira coal power plant, Brazil

Flues, M. *et al. Fuel*, 2013, 103, 430–436.
During operation, the coal power plant produces solid waste (bottom and fly ash) and uncontrolled ashes disposal could lead to environmental contamination. Major and trace elements (Al, Fe, Ti, Ca, Mg, As, Cd, Cr, Co, Cu, Mn, Mo, Ni, Pb, Zn, V) were determined in coal and ashes of the power plant of Figueira (Brazil) and their mobility

evaluated by total and available metal concentration ratio. The total concentration was determined by WDXRF technique and the available concentration (after extraction with EDTA) by ICP-OES technique. The results showed a high total concentration for As and Zn (average 270 and 391 mg kg^{-1}) in coal and (average 974 and 1330 mg kg^{-1}) in fly ashes. The high mobility of As (>70%), followed by Mo (>55%) and next by Mn, Zn, Cd, Pb (30–5%) in ash can cause environmental impact. Arsenic could be considered the most critical element to be leached from ashes.

13/02488 Using game theory to describe strategy selection for environmental risk and carbon emissions reduction in the green supply chain

Zhao, R. *et al. Journal of Loss Prevention in the Process Industries*, 2012, 25, (6), 927–936.

This paper provides an approach in the context of green supply chain management, using game theory to analyse the strategies selected by manufacturers to reduce life cycle environmental risk of materials and carbon emissions. Through the application of the 'tolerability of risk' concept, a basis for determining the extent of environmental risk and carbon emissions reduction has been established. Currently, scant attention is given to holistic supervision of the supply chain with respect to carbon emissions by governments, and thus the starting hypothesis here is that the default strategy that manufacturers will adopt is only to reduce carbon emissions, and thereby environmental risk, in so far as this is compatible with the aim of increasing revenue. Moreover, the authors further hypothesize that, once necessary governmental policy has been established in the supply chain management, the strategic choices of the manufacturers would be influenced by government penalties or incentives. A case example is provided to demonstrate the insight that indicates the application of game theory. The limitations of the game model and analysis are discussed, laying a foundation for further work.

13/02489 Waste materials for carbon capture and storage by mineralisation (CCSM) – a UK perspective

Sanna, A. *et al. Applied Energy*, 2012, 99, 545–554.

This work reviews the advantages and disadvantages of using mineral wastes for CCS and their potential in CO_2 abatement, highlighting the potential applications and scenarios. This study indicates that a variety of inorganic waste materials such as pulverized fuel ash, municipal solid waste ash, cement kiln dust, biomass and paper sludge ash and sewage sludge ash are available feedstocks for carbon capture and storage by mineralization (CCSM) in the UK. The high variability of both the waste amounts and chemical composition represent a major obstacle to the deployment of these materials in CCSM. Currently, mineral waste resources for mineral carbonation have the theoretical potential to capture about 1 Mt/year CO_2 in the UK, considering only the materials not recycled that are currently sent to landfill. Moreover, inorganic waste as a CCSM resource is in many ways more complex than the use of natural minerals due to uncertainty on future availability and high chemical variability and might be viable only in niche applications. For example, the use of inorganic wastes (concrete waste and steel slag) and buffer solutions in spray trickle bed systems (able to sequester 50% of the CO_2 entering the system) was estimated to have costs competitive with geological storage.

CO_2, NO_x, SO_2 and particulate emissions

13/02490 Carbon capture and storage on its way to large-scale deployment: social acceptance and willingness to pay in Germany

Kraeusel, J. and Möst, D. *Energy Policy*, 2012, 49, 642–651.

Carbon capture and storage (CCS) is an emerging technology to mitigate greenhouse gas emissions from fossil fuel-fired power plants. In the wake of a rapidly changing German energy system, CCS can play an important role. By means of an online survey among 130 university students in Dresden, this paper investigates the level and influencing factors of social acceptance of CCS. Furthermore, the individual willingness to pay for CCS and renewable power delivery is measured and compared through a choice model. The survey results reveal that the attitude towards CCS is neutral. Moreover, it is shown that acceptance of CCS is an important factor for the willingness to pay. The level of willingness to pay for CCS technology is much lower than for renewable energy.storage

13/02491 Control of NO_x emissions of a domestic/small-scale biomass pellet boiler by air staging

Liu, H. *et al. Fuel*, 2013, 103, 792–798.

The NO_x emissions of a UK-manufactured domestic/small-scale 50 kW$_{th}$ underfeed stoker biomass pellet boiler were experimentally investigated under different air staging configurations including varying primary to secondary air ratios and different heights of the secondary air inlets above the fuel bed. Two different commercial biomass pellet fuels, i.e. standard Class A wood pellets (fuel-N = 0.13 wt%) and clean waste wood pellets (fuel-N = 0.46 wt%), were used in these tests. The total excess air level of the boiler was kept constant for all air staging configurations. The experimental results show that even with the domestic/small-scale biomass boiler, air staging can be effective and lead to considerable NO_x reductions, particularly with biomass fuels containing relatively high fuel-N. The height of the secondary air inlets above the bed was found to have important impacts on both NO_x and CO emissions. However, the trade-off between NO_x emissions and CO emissions needs to be carefully considered when air staging is used to control NO_x emissions of domestic/small-scale biomass boilers.

13/02492 Copper exchanged ultrastable zeolite Y – a catalyst for NH_3-SCR of NO_x from stationary biogas engines

Ochońska, J. *et al. Catalysis Today*, 2012, 191, (1), 6–11.

NO_x emissions will need to be controlled from gas engines, which in the future could be using a syngas/producer gas as a fuel (generated from the gasification of biomass). In anticipation of this need, the activity of a copper-exchanged ultrastabilized zeolite Y was investigated, for the selective catalytic reduction of NO_x. The catalyst performance and properties were compared with reference samples of Cu-exchanged un-stabilized Y and Cu exchanged ZSM-5 zeolites. Activity was related to the number and nature of active centres, which were determined by *in situ* FTIR and TPD experiments using CO, NO, and NH_3 as probe molecules. In the test reaction the ultrastabilized Cu-USY catalyst showed high activity at low temperatures and offered high hydrothermal resistance, whilst the Cu-ZSM-5 catalyst demonstrated the highest overall activity. The observed low temperature activity of the ultrastabilized Cu-USY catalyst was linked to the high abundance of Cu^+ sites, which were detected by *in situ* FTIR analyses using CO adsorption.

13/02493 Effect of PHB and oxygen uptake rate on nitrous oxide emission during simultaneous nitrification denitrification process

Jia, W. *et al. Bioresource Technology*, 2012, 113, 232–238.

Simultaneous nitrification denitrification (SND) process was achieved in a SBR system to evaluate the impacts of intracellular carbon source poly-hydroxybutyrate (PHB) and oxygen uptake rate (OUR) on nitrous oxide (N_2O) emission. Compared with the sequential nitrification and denitrification (SQND) process, SND process significantly improved the nitrogen removal. N_2O emission during SND process was much higher than the SQND process. The amount of N_2O emission was 26.85 mg N per cycle in SND process, which was almost four times higher than that in SQND process. About 7.05% of the removed nitrogen during SND process was converted to N_2O-N. N_2O emission had great relations with the OUR and the OUR could reflect the N_2O emission trend more exactly than the DO concentration. At the aerobic stage of SND, the simultaneous denitrification could carried out using PHB as the carbon source and N_2O emission increased because of the slow degradation of PHB.

13/02494 Environmental performance of state-owned and privatized eastern European energy utilities

Meyer, A. and Pac, G. *Energy Economics*, 2013, 36, 205–214.

Privatization in eastern Europe has helped in the transition of the region's economies from planned to free market. However, the effects of privatization on the environment are relatively unknown and many firms remain under state ownership today. The authors compare the environmental performance of state-owned and privatized energy utility plants in eastern Europe utilizing a novel panel data that includes reported sulfur dioxide emissions, energy input, and ownership status. They find that state-owned plants emit more sulfur dioxide than privately owned plants; this is environmentally significant as privatization is associated with a reduction in emissions of about 55%.

13/02495 GIS-based location suitability of decentralized, medium scale bioenergy developments to estimate transport CO_2 emissions and costs

Kurka, T. *et al. Biomass and Bioenergy*, 2012, 46, 366–379.

This paper presents a transferable and adaptable GIS-based approach to identify suitable locations of medium-scale combined heat and power (CHP) bioenergy plants. Location suitability of bioenergy plants is of particular importance in planning decentralized bioenergy generation, as both biomass feedstock supplies and heat demand have to be considered in location selection when heat and electricity want to be utilized. A generic GIS model was developed to identify most suitable locations of CHP bioenergy plants based on regional supply, demand and proximity. Furthermore, the paper provides a simple approach to allocate biomass feedstock supplies to bioenergy plants and to estimate transport costs and CO_2 emissions. The GIS-based approach was applied in a Scottish region (Tayside and Fife) to identify locations for 10 decentralized, medium-scale bioenergy plants based on which regional biomass feedstock supplies were allocated and road transport-related CO_2 emissions and costs were estimated. The paper concludes that the approach can assist in developing and implementing a long-term sustainable and integrated strategy for decentralized bioenergy generation, which includes heat utilization in addition to electricity production and which can be further developed to take account of broadly diversified conventional and renewable energy generation in a region.

13/02496 Greenhouse gas emissions from two-stage landfilling of municipal solid waste

Zhang, Y. *et al. Atmospheric Environment*, 2012, 55, 139–143.

Simulations were conducted to investigate greenhouse gas emissions from aerobic pretreatment and subsequent landfilling. The flows in carbon balance, such as gas, leachate, and solid phases, were considered in the simulations. The total amount of CO_2 eq. decreased as organic removal efficiency (ORE) increased. At ORE values of 0, 0.30, 0.41, and 0.54, the total amounts of CO_2 eq. were 2614, 2326, 2075 and 1572 kg CO_2 eq. per one ton dry matter, respectively; gas accounted for the main contribution to the total amount. The reduction in CO_2 eq. from leachate was the primary positive contribution, accounting for 356%, 174% and 100% of total reduction at ORE values of 0.30, 0.41 and 0.54, respectively. The CO_2 eq. from energy consumption was the negative contribution to total reduction, but this contribution is considerably lower than that from gas. Aerobic pretreatment shortened the lag time of biogas production by 74.1–97.0%, and facilitated the transfer of organic carbon in solid waste from uncontrolled biogas and highly polluting leachate to aerobically generated CO_2.

13/02497 Mineral carbonation of flue gas desulfurization gypsum for CO_2 sequestration

Lee, M. G. *et al. Energy*, 2012, 47, (1), 370–377.

In this study, the technical feasibility of the mineral carbonation of flue gas desulfurization (FGD) gypsum to sequester CO_2 was assessed by considering various reaction parameters. Unlike other natural and industrial materials, FGD gypsum showed very high carbonation reactivity at room temperature and atmospheric pressure. Under optimum conditions, calcium carbonate with a purity exceeding 90% could be obtained within 10 min at a carbonation rate of approximately 95%. Thus, mineral carbonation of FGD gypsum was found to be technically feasible. The use of excess ammonia (110–120%) was found to be desirable for enhancing the stability of the reaction and for obtaining high-purity $CaCO_3$. An increase in the CO_2 flow rate accelerated the carbonation reaction significantly but decreased the CO_2 sequestration efficiency. Therefore, the flow rate should be optimized by considering the reaction rate and CO_2 sequestration efficiency. While an increase in the solid-to-solution ratio increased the extent of temperature rise in the slurry, it did not affect the carbonation rate, which remained high at 95% for s/s ratios up to 50%. The use of a CO_2/N_2 gas mixture only slowed the carbonation reaction, and did not affect the $CaCO_3$ purity and carbonation rate.

13/02498 PM_{10} weekly periodicity in Beijing and Tianjin, 2000–2009: anthropogenic or natural contributions?

Choi, Y.-S. and Kim, B.-R. *Atmospheric Environment*, 2012, 55, 49–55.

This study investigates the weekly periodicity of PM_{10} (aerosol particulate matter with a diameter $<10\,\mu m$) mass concentrations over Beijing and Tianjin as well as its relationship with synoptic-scale weather variability. The two cities are large air pollutant source regions that are often affected by the same weather system due to their close proximity. Comparison of the two cities, therefore, advances the understanding of the contributions of the weather variability (or anthropogenic emissions) to the weekly periodicity of PM_{10}. Here the authors analyse PM_{10} anomalies against weekly means over the past 10 years (2000–2009) on the frequency domain using a fast Fourier transform. Results show that the interannual variabilities of PM_{10} weekly periodicity, defined as the ratio of 6–8-day variance to 2–14-day variance, between Beijing and Tianjin are correlated in the summer and fall, but are uncorrelated in the spring. In the fall, the higher correlation of PM_{10} weekly periodicity between the two cities may be associated with strong influence of the natural weather variability as represented by 850-hPa geopotential height, surface diurnal temperature range, and 1000-hPa wind. However, in the spring and summer, the influence of the weather variability on the PM_{10} weekly periodicity was not identified. The weather variability accounts for 0–85% of the PM_{10} weekly periodicity variation, with the maximal value in Beijing in the fall. These findings suggest that contribution of the weather variability to shaping the PM_{10} weekly periodicity over Beijing and Tianjin is restrictive and transient.

13/02499 Quantifying uncertainty of emission estimates in national greenhouse gas inventories using bootstrap confidence intervals

Tong, L.-I. *et al. Atmospheric Environment*, 2012, 56, 80–87.

Greenhouse gas (GHG) emissions have exacerbated global warming, and consequently are the focus of worldwide reduction efforts. Reducing emissions involves accurately estimating GHG emissions and the uncertainty associated with such estimates. The uncertainty of GHG emission estimates is often assessed using the 95% confidence interval. Given a small sample size and non-normal distribution of the underlying population, the uncertainty estimate obtained using the 95% confidence interval may lead to significant bias. Bootstrap confidence interval is an effective means of reducing bias. This work presents a procedure for estimating the uncertainty of GHG emission estimation using bootstrap confidence intervals. Numerical simulation is performed for GHG emission estimates under three distributions (namely normal, log-normal and uniform) to find the 95% confidence intervals and bootstrap confidence intervals. Finally, the accuracy and sensitivity of the uncertainty of various interval estimations are examined by comparing the coverage performance, interval mean and interval standard deviation. Simulation results indicate that the bootstrap intervals are more applicable than the 95% confidence interval given non-normal dataset and small sample size. Moreover, when sample size n is less than 30, the bootstrap confidence interval has a smaller interval length with a smaller deviation than that of the classical 95% confidence interval regardless of whether the data distribution is normal or non-normal. This study recommends a sample size greater than or equal to nine for estimating the uncertainty of emission estimates. When the sample size n exceeds 30, either the normality-based 95% confidence interval or bootstrap confidence intervals may be used regardless of whether the data distribution is normal or non-normal. A case study of carbon stock from Taiwan demonstrates the feasibility of the proposed procedure.

13/02500 SO_2 and NO_2 tolerance of microalgae with the help of some growth stimulators

Taştan, B. E. *et al. Energy Conversion and Management*, 2012, 64, 28–34.

Environmental toxicity of the major acidic pollutants in the flue gas mixtures has long been well known. This study addresses of using *Synechococcus* sp. and *Chlorella* sp. as effective biomaterials in their tolerance to SO_2 and NO_2 and improving their growth and survival by addition of triacontanol (TRIA) and sodium bicarbonate ($NaHCO_3$) to the culture medium. The cultures were exposed to SO_2 or NO_2 for 10′, 15′, and 20′ periods at the tenth day of incubation. Optimum pH was found as 7.5 for *Synechococcus* sp. and 8.5 for *Chlorella* sp. at 10′ exposure to SO_2 or NO_2 gas. Toleration of both microalgal cultures towards NO_2 was better than SO_2. *Chlorella* sp. had much more tolerance to acidic pollutants than *Synechococcus* sp. Chlorophyll *a* concentration of *Synechococcus* sp. was 0.142 µg/mL at 15′ exposure to SO_2, 0.130 µg/mL at 20′ exposure to SO_2, 0.296 µg/mL at 15′ exposure to NO_2, and 0.142 µg/mL at 20′ exposure to NO_2. Chlorophyll ($a + b$) concentration of *Chlorella* sp. was 0.667 µg/mL at 15′ exposure to SO_2, 0.493 µg/mL at 20′ exposure to SO_2, 0.800 µg/mL at 15′ exposure to NO_2, and 0.510 µg/mL at 20′ exposure to NO_2. This study highlights the potential of using *Synechococcus* sp. and *Chlorella* sp. in tolerance to NO_2 and SO_2 from flue gas mixtures at least.

13/02501 Statistical assessment and modeling of the effects of weather conditions on H_2S plume dispersal from Icelandic geothermal power plants

Thorsteinsson, T. *et al. Geothermics*, 2013, 45, 31–40.

Episodes of high atmospheric load of hydrogen sulfide (H_2S), where the concentration is over $50\,\mu g\,m^{-3}$ hourly average value, occur about 80 times a year in Reykjavik (data from 2007 to 2009). H_2S originates mainly from two geothermal power plants 25–30 km (south-)east of Reykjavik, at Hellisheidi and Nesjavellir. Certain weather-dependent dispersion conditions, such as wind, cloud cover and air temperature, allow the transport of emissions towards Reykjavik and the neighbouring cities, causing local air pollution. High concentrations of H_2S occur within a narrow range of weather conditions, namely slow (mean value $2 \pm 1\,m\,s^{-1}$) easterly ($114^\circ \pm 23^\circ$) winds, together with cold air temperatures (median value $-3\,^\circ C$) and preferably no, or little, cloud cover. A classification of weather types shows the preferred occurrence of high H_2S concentrations in connection with low atmospheric exchange and autochthonous weather. Stable atmospheric stratification and inversions enable the transport of H_2S emissions to Reykjavik. The measured concentrations, the short lived peaks in concentration and different values at nearby measurement stations, indicate a very narrow plume, which fits well with a Gaussian plume distribution model.

13/02502 Sulfur dioxide control in China: policy evolution during the 10th and 11th Five-Year Plans and lessons for the future

Schreifels, J. J. *et al. Energy Policy*, 2012, 48, 779–789.

China's Central government established national goals to reduce sulfur dioxide (SO_2) emissions by 10% in both the 10th and 11th Five-Year Plan periods, 2001–2005 and 2006–2010, respectively. But the early policies were unsuccessful at reducing emissions – emissions increased 28% during the 10th Five-Year Plan. After adapting a number of policies and introducing new instruments during the 11th Five-Year Plan, SO_2 emissions declined by 14%. This study examines the evolution of these policies, their interplay with technical and institutional factors, and capture lessons from the 11th Five-Year Plan to guide future pollution control programs. It was found that several factors contributed to achievement of the 11th Five-Year Plan SO_2 reduction goal: (1) instrument choice, (2) political accountability, (3) emission verification, (4) political support, (5) streamlined targets, and (6) political and financial incentives. The approach integrated multiple policy instruments – market-based, command-and-control and administrative instruments specific to the Chinese context. The evolution of SO_2 reduction policies and programs has implications for further SO_2 reductions from power plants and other sources, as well as control of other atmospheric pollutants such as nitrogen oxides (NO_x) and carbon dioxide (CO_2) in China.

Hydrocarbon emissions

13/02503 Anthropogenic PAHs in mangrove sediments of the Calabar River, SE Niger Delta, Nigeria

Oyo-Ita, O. E. *et al. Applied Geochemistry*, 2013, 28, 212–219.

Polycyclic aromatic hydrocarbons (PAHs) in some coastal and mangrove sediments from the Calabar River were determined using GC–MS to assess the degree of contamination. The sediments exhibited significant spatial variations in concentrations of individual and total PAHs (TPAHs) as reflected in the wide range of the values (1670–20,100 ng/g dw) and a mean with a large standard deviation (9370 ± 579), suggesting that the contamination was localized. Mangrove area samples showed much higher TPAH contents, capable of posing a serious health threat to resident flora/fauna, than the coastal samples. A set of seven molecular ratios were calculated to evaluate different PAH sources and their relative importance. The results show that the river was predominated by petroleum-derived PAHs. However, Pyr/Pery and *Pery/PAH_{penta} profiles indicated the importance of a pyrolytic origin for perylene in relation to its diagenetic production. Factor analysis data confirmed this pattern and explained about 70.8% of the total variance.

13/02504 Distribution and sources of polycyclic aromatic hydrocarbons in size-differentiated re-suspended dust on building surfaces in an oilfield city, China

Kong, S. *et al. Atmospheric Environment*, 2012, 55, 7–16.

Thirty re-suspended dust samples were collected from building surfaces in an oilfield city, re-suspended and sampled through $PM_{2.5}$, PM_{10} and PM_{100} inlets and analysed for 18 PAHs by GC–MS technique. PAHs concentrations, toxicity and profiles characteristic for different districts and size were studied. PAHs sources were identified by diagnostic ratios and primary component analysis. Results showed that the total amounts of analysed PAHs in re-suspended dust in Dongying were 45.29, 23.79 and 11.41 $\mu g\, g^{-1}$ for $PM_{2.5}$, PM_{10} and PM_{100}, respectively. PAHs tended to concentrate in finer particles with mass ratios of $PM_{2.5}/PM_{10}$ and PM_{10}/PM_{100} as 1.96 ± 0.86 and 2.53 ± 1.57. The old district with more human activities and long oil exploitation history exhibited higher concentrations of PAHs from both combustion and non-combustion sources. BaP-based toxic equivalent factor and BaP-based equivalent carcinogenic power exhibited decreasing sequence as $PM_{2.5} > PM_{10} > PM_{100}$ suggesting that the finer the particles, the more toxic of the dust. NaP, Phe, Flu, Pyr, BbF and BghiP were the abundant species. Coefficient of divergence analysis implied that PAHs in different districts and size fractions had common sources. Coal combustion, industrial sources, vehicle emission and petroleum were probably the main contributions according to the principal component analysis result.

13/02505 Factors affecting the level and pattern of polycyclic aromatic hydrocarbons (PAHs) at Gosan, Korea during a dust period

Choi, S.-D. *et al. Journal of Hazardous Materials*, 2012, 227–228, 79–87.

Polycyclic aromatic hydrocarbons (PAHs) in both gas and total suspended particles were measured at Gosan, Jeju Island in Korea, a remote background site, for 15 days (29 March to 12 April 2002). During the sampling period, a severe three-day Asian dust (AD) event originating from Mongolia and northern China was observed throughout the Korean Peninsula and Jeju Island. In addition, pollution (PO) and normal (NO) periods were also identified based on the levels of anthropogenic pollutants. Despite a large difference of PM_{10} concentrations between the AD and PO periods, the levels of particulate PAHs in both periods were comparable (2.7 ± 1.0 and $2.4 \pm 0.5\, ng\, m^{-3}$, respectively) since they were determined by the concentration of anthropogenic $PM_{2.5}$ transported from industrial areas of China. In the AD period, the level of gaseous PAHs, which were mostly from local sources, was the lowest due to strong winds; the gas/particle partitioning was close to equilibrium as the effect of long-range transport was manifested. The results of backward air trajectories, correlation analysis, and diagnostic ratios show that long-range transport of particulate PAHs produced by coal/biomass burning in China could strongly affect the levels and patterns of PAHs at Gosan, Korea.

13/02506 Impact of coconut oil blends on particulate-phase PAHs and regulated emissions from a light duty diesel engine

How, H. G. *et al. Energy*, 2012, 48, (1), 500–509.

Biofuel is a prominent alternative fuel because of its environmental benefits and similar physiochemical properties to diesel fuel. This study investigated the impact of high quality refined, bleached and deodorized (RBD) coconut oil blends and fuel throttle setting on performance and exhaust emissions of diesel engine. The criteria regulated emissions and particulate-phase polycyclic aromatic hydrocarbons (PAHs) were studied. The engine was operated with pure diesel and blended fuels contain of 10%, 30% and 50% of coconut oil by volume. Experiments were conducted under 75% and 50% throttle opening conditions at 2000 rpm. The use of coconut oil blends resulted in a reduction of all of the regulated emissions, except for slight fluctuations in CO_2 emissions. There was no significant difference in total PAH emissions with the different throttle settings. All the coconut oil blends showed lower PAH emissions except for fluoranthene and benzo[a]pyrene compounds. Notably, coconut oil blends resulted in a maximum reduction of 40% in total PAH concentration. It was observed that coconut oil blends increased the total benzo[a]pyrene equivalent (Ba_{Peq}). However, the reduction in benzo[a]anthracene indicated the positive effects on toxicity reduction of coconut oil as a potential substitute for fossil diesel.

13/02507 Pilot scale *ex-situ* bioremediation of heavily PAHs-contaminated soil by indigenous microorganisms and bioaugmentation by a PAHs-degrading and bioemulsifier-producing strain

Sun, G.-D. *et al. Journal of Hazardous Materials*, 2012, , 72–78.

This study aims at the remediation of heavily polycyclic aromatic hydrocarbons (PAH)-contaminated soil containing 375 mg of total PAHs per kilogram dry soil. Pilot scale bioremediation experiments were carried out by three approaches with contaminated soil from abandoned sites of Beijing coking plant using outdoor pot trials. The first approach was bioaugmentation with a bacterial strain which degrades PAH and produces bioemulsifier, the second approach comprised of biostimulation of indigenous microorganisms with supplementing nutrients and the last approach involved the combination of both biostimulation and bioaugmentation. An on-site land farming group was set as a control in which the total PAHs and four to six ring-PAHs were reduced by 23.4% and 10.1%, respectively after 175 days. Meanwhile, in the first approach group, the total PAHs and four to six ring-PAHs were reduced by 26.82% and 35.36%, respectively; in the second approach group both percentages were 33.9% and 11.0%, respectively; while in the third approach group, these pollutants were reduced by 43.9% and 55.0%, respectively. The results obtained suggested that biostimulation and bioaugmentation combined could significantly enhance the removal of PAHs in the contaminated soil.

Life cycle analysis

13/02508 A comparison of deterministic and probabilistic life cycle cost analyses of ground source heat pump (GSHP) applications in hot and humid climate

Zhu, Y. *et al. Energy and Buildings*, 2012, 55, 312–321.

Geothermal energy is widely considered as an ideal alternative energy for building operations. Despite the fact that ground source heat pumps (GSHPs) have been studied for decades, including economic analyses such as life cycle costing, their technical and economic applicability in hot and humid climate such as Florida, USA is yet to be determined. In the past, many life cycle cost analyses on GSHPs were conducted using a deterministic method to derive point estimates. In many cases, data were assumed, but data uncertainties were not accounted for. In this study, a comparison of the deterministic and the probabilistic method was performed in order to understand the impact of data uncertainties on results of analyses. The probabilistic life cycle cost analysis was based on Monte Carlo simulation. A GSHP application case in Pensacola, Florida was selected for the comparison. Some data were collected through site visits or interviews, while others were gathered from the literature or published data. Probability distribution functions used by Monte Carlo simulation were derived based on historical data or assumptions. Results of the case study from both deterministic and probabilistic methods confirmed that the GSHP option was economically more favourable than a conventional single zone split system using heat pumps, but with a long payback time if incentives were not considered. The probabilistic method was found to deliver a more reliable conclusion with more critical information than the deterministic method. However, further studies were needed to verify those initial observations obtained from this case study.

13/02509 A life cycle assessment (LCA) comparison of three management options for waste papers: bioethanol production, recycling and incineration with energy recovery

Wang, L. *et al. Bioresource Technology*, 2012, 120, 89–98.

This study uses life cycle assessment (LCA) to assess the environmental profiles and greenhouse gas (GHG) emissions for bioethanol production from waste papers and to compare them with the alternative waste management options of recycling or incineration with energy recovery. Bioethanol production scenarios both with and without pretreatments were conducted. It was found that an oxidative lime pretreatment reduced GHG emissions and overall environmental burdens for a newspaper-to-bioethanol process whereas a dilute acid pretreatment raised GHG emissions and overall environmental impacts for an office paper-to-bioethanol process. In the comparison of bioethanol production systems with alternative management of waste papers by different technologies, it was found that the environmental profiles of each system vary significantly and this variation affects the outcomes of the specific comparisons made. Overall, a number of configurations of bioethanol production from waste papers offer environmentally favourable or neutral profiles when compared with recycling or incineration.

13/02510 A methodology for estimating the life-cycle carbon efficiency of a residential building

Li, D. Z. *et al. Building and Environment*, 2012, 59, 448–455.

Residential buildings account for a large share of global carbon emission, while they play important roles in economic growth and social development at the same time. Therefore, the appropriate evolution routes of residential buildings need balancing their carbon emission and value creation, which is realized in this paper by creating a new concept of life-cycle carbon efficiency and its relative methodology. First, the life-cycle carbon efficiency of a residential building is defined as the ratio of its life-cycle value to carbon emission, and the life-cycle of a residential building is divided into five stages, including construction materials preparation, building construction, building operation, building demolition, and construction and demolition wastes disposal. Second, the life-cycle carbon emission of a residential building is estimated through calculating the carbon emission at each stage based on its consumed energy and resources. Third, the product of the service life span of a residential building (in year), its building area (m^2) and its storey height (m) is recommended to represent its life-cycle value, since this product is a physical measure and more useful to develop action plans to improve its performance. In the end, the proposed methodology is exemplified in estimating the life-cycle carbon efficiency of a five-storey brick-concrete residential building in Nanjing city (China) at its design phase. Possible measures to enhance the estimated carbon efficiency are further put forward, such as prolonging the service life span, enhancing the principles of reduce, reuse and recycle of cement and rolled steel, saving electricity and natural gas at the stage of building operation.

13/02511 Biofuel production from crude palm oil with supercritical alcohols: comparative LCA studies

Sawangkeaw, R. *et al. Bioresource Technology*, 2012, 120, 6–12.

A recent life cycle assessment (LCA) reported that biodiesel production in supercritical alcohols (SCA) produces a higher environmental load than the homogeneous catalytic process because an enormous amount of energy is required to recover excess alcohol. However, the excess alcohol could be dramatically reduced by increasing the operating temperature to 400 °C; although the product would have to be considered as an alternative biofuel instead of biodiesel. A comparative LCA of the biodiesel production in two SCA at 300 °C (C-SCA) and novel biofuel production in the same two SCA at 400 °C (N-SCA) is presented. It was clear that the N-SCA process produces a dramatically reduced environmental load over that of the C-SCA process due to a lower amount of excess alcohol being used. The N-SCA process could be improved in terms of its environmental impact by changing from fossil fuel to biomass-based fuels for the steam generation.

13/02512 Comparison of life cycle energy consumption and GHG emissions of natural gas, biodiesel and diesel buses of the Madrid transportation system

García Sánchez, J. A. *et al. Energy*, 2012, 47, (1), 174–198.

This paper presents a comparative study on the use of three after-treatment technologies: (i) EGR + DPF, (ii) SCR + urea and (iii) three-way catalyst when implemented in urban buses, to determinate the energy requirements, greenhouse gas emissions (GHG), direct land use change (dLUC), abiotic depletion of fossil energy by means of a life cycle assessment (LCA). The process of production, conditioning and transporting of the fuels used by the buses [diesel, biodiesel (B100), a blended biodiesel at 20% (B20) and natural gas] were also analysed (well-to-tank analysis) along with the environmental impact due to its combustion in the bus (tank-to-wheel analysis). The environmental impact of the manufacturing, maintenance and recycling process of the urban buses and exhaust after-treatment systems has also been evaluated. Main results shows that life cycle of SCR + urea technology reduces environmental impact to a greater extent than its global life cycle increases it when gasoil is used resulting in a final balance more efficient than the other options, the same behaviour is observed with the use of B20 and B100 but only when 0%dLUC is assumed since if the percentage of dLUC increases the effectiveness of the SCR + urea technology in the reduction of environmental impact tend to decrease.

13/02513 Economic and ecological indicators for thermal insulating building investments

Dylewski, R. and Adamczyk, J. *Energy and Buildings*, 2012, 54, 88–95.

Approximately 50 of final energy in Europe is used in buildings (about 50%). Thermoinsulating investments in the building sector can have a great impact on the improvement of the energetic efficiency of buildings and the reduction of the use of final energy in this sector. The paper presents properly modified indicators for the economic assessment of the investments which is based on the thermal insulation of external walls of the building, such as: net present value, profitability indicator and payback period. For the ecological assessment the following indicators were introduced: ecological net present value, ecological indicator of profitability and ecological payback period. LCA technique was used in ecological indicators. For different variants of external walls, sources of heat and thermo insulating materials, the assessment of investments due to economic and ecological indicators was conducted. Ecological payback periods were obtained within 0–6 years.

13/02514 Life cycle approach in evaluating energy performance of residential buildings in Indian context

Ramesh, T. *et al. Energy and Buildings*, 2012, 54, 259–265.

The paper presents life cycle energy (LCE) analysis of different types of residential buildings (one-storey, two-storey, and duplex and multi-storey) in Indian context. A total of 10 houses' designs were examined with energy saving features, e.g. thermal insulation on wall and roof, double pane glass for windows. One of these buildings was further examined to assess LCE performance with on-site power generation. Dynamic energy simulation tools DesignBuilder, e-Quest and EnergyPlus were used to assess energy performance of the buildings. LCE of the buildings is varying from 240 to 380 $\mathrm{kWh/m^2}$ year depending on the type (envelope) of the building and climatic conditions. LCE savings of about 5–30% are observed with thermal insulation on wall and roof along with double pane glass for windows. It is found that net zero operating energy building can be achieved by on-site power generation from PV and wind turbine. LCE of the building for net zero operating energy is evaluated to be 71.24 $\mathrm{kWh/m^2}$ year.

13/02515 Life cycle assessment approach for the optimization of sustainable building envelopes: an application on solar wall systems

Stazi, F. *et al. Building and Environment*, 2012, 58, 278–288.

Design of sustainable building envelopes requires the analysis of environmental performances in every stage of their life cycle. As a matter of fact, the production phase of building materials and components can significantly contribute to the total energy consumption and environmental loads of buildings. However, façade systems such as passive solar systems, ventilated walls and double skins, are usually not designed considering aspects related to their life cycle. Furthermore, there are still few studies concerning the optimization and the combined effect of different design features of complex façades on environmental and energy performances. This paper introduces an integrated approach for the optimization of energy and environmental performances of complex building envelopes that combines life cycle assessment, energy simulation and optimization analysis with factorial plan technique. The environmental performance was calculated in terms of energy demand and CO_2 emissions in the production phase and operational phase. The methodology was applied to an exemplary case study with solar wall systems. The results showed that solar walls have high environmental impact both in the production and operational phases. Results of the optimization analysis demonstrated that it is possible to reduce the CO_2 emissions and cumulative energy demand of solar walls for both the production and use phases up to −55% in comparison with a traditional design. This methodology may be generally applied to the sustainability analysis, design and optimization of efficient façade systems.

13/02516 Life cycle assessment of a single-family residence built to either conventional- or passive house standard

Dahlstrøm, O. *et al. Energy and Buildings*, 2012, 54, 470–479.

The environmental and resource impacts of wooden single-family residences designed to meet the conventional Norwegian Building Code from 2010 (TEK10) and the Norwegian passive house standard NS 3700 are compared using life cycle assessment. Four different heating systems are evaluated for the two building designs: (1) electric (resistance heating), (2) electric and wood, (3) electric and a solar heat collector and (4) electric and an air–water heat pump system. The goal of the research is to evaluate the different ways of lowering the total environmental burden of a building's life cycle, considering the two building standards, and evaluating the impacts due to implementation of renewable heating systems in comparison to standard Norwegian systems largely based on electricity. The life cycle results show that the wood-framed single-family residence built according to the passive house standard provides a consistent and clear reduction of cumulative energy demand of 24–38% in comparison to the conventional building standard TEK10 with electric panel heating. In combination with efficient heating systems, a passive house building envelope with a heat pump system provides the largest savings, an improvement of almost 40% compared to a conventional house with electric heating. The reduction in greenhouse gas emissions of the cleanest design compared to the standard alternative is almost 30%. Solar heated water also provides substantial environmental gains for the passive house. On the other hand, a standard building envelope with a heat-pump system reduces impacts to a level comparable to that of a passive house building with only electric heating.

13/02517 Life cycle greenhouse gases and non-renewable energy benefits of kraft black liquor recovery

Gaudreault, C. *et al. Biomass and Bioenergy*, 2012, 46, 683–692.

The life cycle greenhouse gas (GHG) and fossil fuel benefits of black liquor recovery are analysed. These benefits are due to the production of energy that can be used in the pulping process or sold, and the recovery of the pulping chemicals that would otherwise need to be produced from other resources. The fossil GHG emissions and non-renewable energy consumption of using black liquor in the kraft recovery system are approximately 90% lower than those for a comparable fossil fuel-based system. Across all scenarios, the systems relying on black liquor solids achieve a median reduction of approximately 140 kg CO_2 eq./GJ of energy produced, compared to the systems relying on fossil fuels to provide the same energy and pulping chemical production functions. The benefits attributable to the recovery of pulping chemicals vary from 44% to 75% of the total benefit. Applied to the total production of kraft pulp in the USA, the avoided emissions are equivalent to the total Scopes 1 and 2 emissions from the entire US forest products industry. These results do not depend on the accounting method for biogenic carbon (because biogenic CO_2 emissions are the same for the systems compared) and the results are valid across a range of assumptions about the displaced fossil fuel, the GHG-intensity of the electricity grid, the fossil fuels used in the lime kiln, and the level of cogeneration at pulp and paper mills. The benefits occur without affecting the amount of wood harvested or the amount of chemical pulp produced.

13/02518 Minimization of the LCA impact of thermodynamic cycles using a combined simulation-optimization approach

Brunet, R. *et al. Applied Thermal Engineering*, 2012, 48, 367–377.

This work presents a computational approach for the simultaneous minimization of the total cost and environmental impact of thermodynamic cycles. This method combines process simulation, multi-objective optimization and life cycle assessment (LCA) within a unified framework that identifies in a systematic manner optimal design and operating conditions according to several economic and LCA impacts. This approach takes advantages of the complementary strengths of process simulation (in which mass, energy balances and thermodynamic calculations are implemented in an easy manner) and rigorous deterministic optimization tools. The authors demonstrate the capabilities of this strategy by means of two case studies in which they address the design of a 10 MW Rankine cycle modelled in Aspen Hysys, and a 90 kW ammonia–water absorption cooling cycle implemented in Aspen Plus. Numerical results show that it is possible to achieve environmental and cost savings using this rigorous approach.

13/02519 Regional life cycle assessment of soybean derived biodiesel for transportation fleets

Xue, X. *et al. Energy Policy*, 2012, 48, 295–303.

Although the life cycle environmental impacts of biofuels have been recently reported, studies that focus on specific regions and use real fleet data for the use phase are still lacking. In Pennsylvania, the Penn Security Fuels Initiative required 2% biodiesel (B2), effective on 1 January 2010, with higher blending levels required in the future if production thresholds are met. This study quantifies the environmental impacts of biodiesel blends to meet increasing regional biodiesel demand. A process life cycle model was developed using data collected from collaboration with Pennsylvania Department of Transportation. For PennDOT, both in-state and out-of-state production scenarios were analysed to estimate the possible environmental impacts of biodiesel blends. The results show that fertilizer usage in the agricultural phase, soy oil extraction and refining, feedstock and fuel transportation, and fuel combustion in the use phase are main contributors to biodiesel's life cycle environmental impacts for all blends. Comparing biodiesels with ultra-low sulfur diesel, significant environmental tradeoffs exist between global warming potential and eutrophication. For Pennsylvania, an in-state farming and processing preference has the lowest environmental impacts for B5. However, the limited area of farmlands in Pennsylvania may not satisfy the state's biodiesel needs with higher blending levels.

13/02520 Scenario uncertainties in estimating direct land-use change emissions in biomass-to-energy life cycle assessment

Curtright, A. E. *et al. Biomass and Bioenergy*, 2012, 47, 240–249.

The use of biomass for energy production has increasingly been encouraged in the USA, in part motivated by the potential to reduce greenhouse gas (GHG) emissions relative to fossil fuels. However, the GHG-intensity of biomass-derived energy is highly dependent on how the biomass is obtained and used. The authors explore scenario uncertainty in GHG estimates in the calculating uncertainty in biomass emissions (CUBE) model and find that direct land-use change emissions that result during the biomass production often dominate the total 'farm-to-hopper' GHGs. CUBE represents each land-use change decision as a conversion of land from one of four specified baseline ecosystem to produce one of seven feedstock crops, both distinct by geographic region, and then determines the implied changes in soil organic carbon, root carbon, and above-ground biomass. CUBE therefore synthesizes and organizes the existing literature to represent direct land-use change emissions in a way that can be more readily incorporated into life cycle assessment. The approach to representing direct land-use change literature has been applied to a specific set of data and offers immediate implications for decision-makers, but it can also be generalized and replicated in the future, making use of improved scientific data on the magnitude and rates of direct land-use change emissions as it becomes available.

13/02521 The cost of green roofs disposal in a life cycle perspective: covering the gap

Peri, G. *et al. Energy*, 2012, 48, (1), 406–414.

This papers aims at providing a contribution in overcoming the current gap, especially in life cycle costing (LCC) and benefit–cost (BCA) analyses, of the costs relating to green roof disposal. The authors have applied the LCC methodology suggested by Woodward (one of the most formalized and generalizable) to an actual extensive green roof. They have also extended the analysis to include the disposal phase. This will allow a complete and proper application of the LCC methodology in order to achieve an economic accounting of this component through its life cycle. In this way, it is possible to achieve the complete evaluation of the 'green roof' performance by a life cycle perspective (the environmental performance, in fact, is assessed by means of the classical life cycle assessment approach). Necessary steps to accomplish the cost analysis of the disposal phase of this building component have been applied and discussed. These steps help to formalize the procedure, so attributing it an approach that may be generalized. The relative contribution of production, maintenance and end-of-life phases to the whole cost of this extensive green roof has also been illustrated.

13/02522 The embodied energy and emissions of a high-rise education building: a quantification using process-based hybrid life cycle inventory model

Chang, Y. *et al. Energy and Buildings*, 2012, 55, 790–798.

Due to the lack of energy intensity data for building materials and the high integration of the construction sector in national input–output tables, applications of conventional process-based life cycle inventory (LCI) and input–output (I–O) LCI models are hindered in China. This study developed a process-based hybrid LCI model to calculate the embodied energy and emissions of a typical high-rise building in China, which has a frame-shear wall and reinforced concrete frame structure. The I–O model used for building materials manufacturing is based on the 2007 Chinese economic benchmark statistics. The process-based model uses the specific data of transportation and construction activities. Results show that the embodied energy of the case building was 309,965 GJ and, the energy intensity is 6.3 GJ m^{-2}. The embodied energy is dominated by coal and the shares of diesel fuel and electricity in total energy were significant. The embodied emissions mainly derive from the electricity sector and gas and water production due to its intensive coal consumption. Results of the process-based hybrid model were moderately higher (5–13%) than the I–O model values.

13/02523 Towards a comprehensive life cycle energy analysis framework for residential buildings

Stephan, A. *et al. Energy and Buildings*, 2012, 55, 592–600.

Current assessments of residential building energy demand focus mainly on operational energy, notably in thermal terms. The embodied energy of buildings and the transport energy consumption of their users are typically overlooked. Recent studies have shown that these two energy demands can represent more than half of the life cycle energy over 50 years. This article presents a framework which takes into account energy requirements at the building scale, i.e. the embodied and operational energy of the building and its refurbishment, and at the city scale, i.e. the embodied energy of nearby infrastructures and the transport energy (direct and indirect) of its users. This framework has been implemented through the development of a software tool which allows the rapid analysis of the life cycle energy demand of buildings at different scales. Results from two case studies, located in Brussels, Belgium and Melbourne, Australia, confirm that each of the embodied, operational and transport requirements are nearly equally important. By integrating these three energy flows, the developed framework and software provide building designers, planners and decision-makers with a powerful tool to effectively reduce the overall energy consumption and associated greenhouse gas emissions of residential buildings.

13/02524 Well-to-wheels life-cycle analysis of alternative fuels and vehicle technologies in China

Shen, W. *et al. Energy Policy*, 2012, 49, 296–307.

A well-to-wheels life cycle analysis on total energy consumptions and greenhouse gas (GHG) emissions for alternative fuels and accompanying vehicle technologies has been carried out for the base year 2010 and projected to 2020 based on data gathered and estimates developed for China. The fuels considered include gasoline, diesel, natural gas, liquid fuels from coal conversion, methanol, bio-ethanol and biodiesel, electricity and hydrogen. Use of liquid fuels including methanol and Fischer–Tropsch derived from coal will significantly increase GHG emissions relative to use of conventional gasoline. Use of starch-based bio-ethanol will incur a substantial carbon disbenefit because of the present highly inefficient agricultural practice and plant processing in China. Electrification of vehicles via hybrid electric, plug-in hybrid electric and battery electric vehicle technologies offers a progressively improved prospect for the reduction of energy consumption and GHG emission. However, the long-term carbon emission reduction is assured only when the needed electricity is generated by zero- or low-carbon sources, which means that carbon capture and storage is a necessity for fossil-based feedstocks. A plug-in hybrid vehicle that runs on zero- or low-carbon electricity and cellulosic ethanol may be one of the most attractive fuel-vehicle options in a carbon-constrained world.

13/02525 Yields and greenhouse gas emissions of cultivation of red clover-grass leys as assessed by LCA when fertilised with organic or mineral fertilisers

Hakala, K. *et al. Biomass and Bioenergy*, 2012, 46, 111–124.

Red clover-grass leys incorporating three clover (*Trifolium pratense* L.) varieties and two grass species, tall fescue (*Festuca arundinacea* Schreb) and timothy (*Phleum pratense* L.), were sown in 2003 and grown for three harvest years (2004–2006). The crops were fertilized either once with organic fertilizer (cow manure applied in the sowing year) or yearly with mineral fertilizer. The yields of the harvested biomasses were measured and the greenhouse gas (GHG) emissions estimated by life cycle analysis (LCA) yearly for both fertilization types. At the end of the experiment, the carry-over effect of the red clover-grass leys was studied with spring wheat (*Triticum aestivum* L.). Mineral fertilization resulted in higher yields, but also about two to three times higher GHG emissions per unit clover-grass biomass than organic fertilization. Grasses were favoured by mineral fertilization, while the proportion of clover was higher and decreased less with time with organic fertilization. Clover leys sown without grasses yielded least and produced the highest emissions per unit biomass. Tall fescue sown with clover produced more consistent yields than timothy, especially during drought stress and when the ley aged. Organic fertilization appears the most sustainable way to produce field biomass for energy, at least when legumes are sown in the ley. After three years of clover-grass production, the biomass yield of spring wheat sown without fertilizer was about 4 t ha^{-1}, which could augment production of biomass per parcel, and would decrease the amount of GHG emissions from bioenergy production whether fertilized with organic or mineral fertilizers.

16 ENERGY

Supplies, policy, economics, forecasts

13/02526 A framework for the optimization of integrated energy systems

Jain, N. and Alleyne, A. G. *Applied Thermal Engineering*, 2012, 48, 495–505.

This paper introduces an exergy-based objective function for the steady-state optimization and control of integrated energy systems (IESs). The use of exergy destruction as the metric for minimization enables the objective function to be scalable with respect to (1) subsystem configuration and (2) subsystem capacity, thereby rendering the approach generalizable to a wide class of IESs. More specifically, exergy destruction can be used to characterize irreversibilities across multiple energy domains (chemical, electrical, mechanical, thermal) which makes it very suitable for the types of energy subsystems which comprise IESs. The approach presented in this paper couples the exergy-based optimization with a feedforward control framework which uses static models to estimate the control inputs required to achieve the optimal setpoints. It is shown that the physical significance obtained using an objective function derived from first-principles makes the objective modular and therefore easily generalizable to complex IESs.

13/02527 A method for energy classification of hotels: a case-study of Greece

Farrou, I. *et al. Energy and Buildings*, 2012, 55, 553–562.

Hotels are a diverse building type with high normalized energy end-use because of its focus to provide best facilities for guests. There is scope, and in many countries legislative requirements, to reduce energy consumption without compromising facilities; case-studies from tourism intensive countries could be useful for demonstrating such possibilities. This paper presents a method of deriving energy benchmarks to enable classification of hotels in Greece based on operational energy use in terms of electricity and oil. The method of classification defines clusters of hotels using the k-means algorithm controlled with the silhouette plot after applying normalization factors for the operational energy data to correct for size, operation (seasonal or annual) and climatic conditions. Ninety hotels are analysed in the sample presented in this paper; and well separated clusters are defined for the whole sample and for the sample split in hotels with annual and seasonal operation. Energy consumption varies considerably between and within clusters indicating that a range of energy consumption targets might be more suitable than single value benchmarks for this type of building.

13/02528 Advances on technical, policy and market aspects of cool roof technology in Europe: the Cool Roofs project

Synnefa, A. and Santamouris, M. *Energy and Buildings*, 2012, 55, 35–41.

Cool roof technology is an energy efficient, financially viable and sustainable solution for mitigating heat islands and reducing building energy consumption for cooling. A European Union (EU) supported project called Cool Roofs has achieved to promote this technology in the EU by the implementation of an action plan. The work is developed in four axes, technical, market, policy and end-users. The action plan is steered by the development of the European Cool Roof Council that brings together all related stakeholders. The main results of the project include the creation of the European Cool Roof Council, five cool roof pilot studies, a database of cool roofing materials, a handbook and a toolkit to assist the better understanding of the technical aspects of the technology, a market promotion plan, a proposal for a successful strategy to overcome possible policy barriers and engage with key stakeholders who could support and accelerate the creation of an EU policy and regulatory friendly environment to cool roofs, the organization of workshops and seminars and other actions of dissemination. This paper presents the main achievements at EU level regarding the establishment of cool roofs as heat island mitigation strategy and a measure for reducing cooling loads.

13/02529 An alternative approach to indirect land use change: allocating greenhouse gas effects among different uses of land

Kim, S. *et al. Biomass and Bioenergy*, 2012, 46, 447–452.

Indirect land use change (iLUC) is hypothesized to occur when increasing demand for land due to bioenergy production displaces food and feed production onto new lands, thereby potentially producing large greenhouse gas emissions (GHG) during the land conversion event. Thus far, the totality of the projected iLUC effect has been assigned to biofuel production. In fact, multiple drivers of land use change exist and the resulting GHG releases should, in fairness, be allocated among these drivers. It seems more useful and intellectually rigorous to allocate potential land use change effects among these many drivers. This paper focuses on how to allocate the environmental consequences of iLUC to the multiple drivers through a function-oriented approach, namely human nutritional requirements for calories and protein. 'Food versus biofuel' issues can then be more usefully addressed as 'nutrition versus biofuel' issues. Human beings actually have many choices in how to provide ourselves with adequate diets, and these choices have very different GHG and land use consequences. Therefore, in this paper, GHG assigned to iLUC is allocated between ethanol and human dietary preferences via a human nutrition-based method. Applying allocation approaches to iLUC lowers the estimated GHG of iLUC by up to 73% compared to GHG estimates in the GTAP model. For example, global warming intensity (GWI) of ethanol measured as CO_2 equivalent becomes $58.2\,g\,MJ^{-1}$, while GWI of ethanol calculated using GREET is $68.9\,g\,MJ^{-1}$.

13/02530 An assessment of land availability and price in the coterminous United States for conversion to algal biofuel production

Venteris, E. R. *et al. Biomass and Bioenergy*, 2012, 47, 483–497.

Realistic economic assessment of land-intensive alternative energy sources (e.g. solar, wind, and biofuels) requires information on land availability and price. Accordingly, the authors created a comprehensive, national-scale model of these parameters for the USA. For algae-based biofuel, a minimum of $1.04E+05\,km^2$ (1.3% of coterminous US land area) of land is needed to meet the Energy Independence and Security Act of 2007 advanced biofuels target of $1.04E+8\,m^3\,yr^{-1}$, to be achieved by the year 2022. In this study, the authors locate and quantify land categories where land acquisition costs and economic disruption are minimized. A data-driven model calculates the incentive to sell and a fair compensation value (real estate and lost future income). A total of $1.02E+06\,km^2$ (14% of CONUS) of low-slope, non-protected land is relatively available including croplands, pasture/grazing, and forests. Within this total there is $2.64E+5\,km^2$ of shrub and barren land available. The Federal government has $7.68E+4\,km^2$ available for lease. Targeting unproductive lands minimizes land costs and impacts to existing industries. However, many shrub and barren lands are limited by other resources (water) and logistics, so land use conversion requires careful consideration in tradeoff analysis.

13/02531 Auditing and analysis of energy consumption of an educational building in hot and humid area

Sait, H. H. *Energy Conversion and Management*, 2013, 66, 143–152.

Electric energy consumption is becoming an important issue for individual as well as for governmental and private organizations. Electric companies in Saudi Arabia face hard times in meeting the increasing demand for electric power. This research investigation is trying to study the electric energy consumption for an educational building located in Rabigh city, 150 km north of Jeddah city, Saudi Arabia. Detailed auditing was done to the building including constructing materials used, energy consumption, cooling load and lighting. Temperature and relative humidity were recorded for several places inside the building. Thermal images for the interior zones were generated to provide information about the temperature distribution and give an idea about air or heat leak from or into the building. Based on the analysis of auditing exercise, some recommendations were suggested to reduce the electric energy consumptions which can reach up to 35.3%. The air-conditioning units' efficiency can also be increased by 31%. The results will be beneficial for the educational organizations and operation and maintenance staff to manage the electric usage and reduce the electric bills.

13/02532 Brazilian sugarcane bagasse: energy and non-energy consumption

Hofsetz, K. and Silva, M. A. *Biomass and Bioenergy*, 2012, 46, 564–573.

Sugarcane is an important crop for economic development of Brazil, once it represents an ethanol and sugar source, as well as the biomass residue (bagasse) that is used for electric energy production. Due to its increasing potential uses, sugarcane bagasse was analysed for energy and non-energy consumption in this work. For that, the amount of bagasse used for this purpose since 1999/2000 to 2012/2013 seasons was discussed as well as the energy from sugarcane bagasse commercialized on energy auctions in Brazil. Additionally, an estimative of bagasse quantity to be used for electric energy and for second-generation ethanol for 2015 and 2030 was shown. The volume of sugarcane bagasse production has increased year by year, and it is possible to observe that there is an increase amount of available bagasse being used for power generation (energy consumption), in cogeneration arrangements. The Brazilian Energy Plan scenarios estimate a mass sugarcane bagasse offering to be used only for second-generation ethanol around 7.0×10^6 tonnes year^{-1} for 2015, and 25.9×10^6 tonnes year^{-1} for 2030. Apart from the bagasse that provides all energy required by sugarcane process, mills can generate an energy surplus and sell it to the grid. Power generation from sugarcane bagasse has been made possible through financing by the Brazilian Program of Incentives for Alternative Sources of Electrical Power which is a renewable energy and can be commercialized through energy auctions.

13/02533 China's energy demand and its characteristics in the industrialization and urbanization process

Jiang, Z. and Lin, B. *Energy Policy*, 2012, 49, 608–615.

China is currently in the process of industrialization and urbanization, which is the key stage of transition from a low-income country to a middle-income country and requires large amount of energy. The process will not end until 2020, so China's primary energy demand will keep high growth in the mid-term. Although each country is unique considering its particular history and background, all countries are sharing some common rules in energy demand for economic development. Based on the comparison with developed countries, here, this study reports some rules in the process of industrialization and urbanization as follows: (1) urbanization always goes along with industrialization; (2) the higher economic growth is, the higher energy demand is; (3) economic globalization makes it possible to shorten the time of industrialization, but the shorter the transition phase is, the faster energy demand grows; (4) the change of energy intensity presents as an 'inverted U' curve, but whose shape can be changed for different energy policy. The above rules are very important for the Chinese government in framing its energy policy.

13/02534 Comparative assessment of residential energy options in Ontario, Canada

Ozlu, S. *et al. Energy and Buildings*, 2012, 55, 674–684.

In this paper, the electricity, heating and cooling demands of a southern Ontario residence are assessed and compared. Five specific systems are analysed: ground and air source heat pumps, stand-alone photovoltaic (PV), PV/fuel cell hybrid and a wind turbine/fuel cell hybrid system. Actual monitored data from a residence using a ground source heat pump is taken as a reference and compared with the others. Average weather conditions, electricity prices and average electricity loads in Toronto, Ontario, are used as reference data. Thermodynamic, economic and environmental comparisons are performed. It is found that heat pump systems offer significant advantages over the other systems.

13/02535 Definitions of fuel poverty: implications for policy

Moore, R. *Energy Policy*, 2012, 49, 19–26.

This paper outlines why the definition of fuel poverty is important in policy formulation and describes how the Government's current definitions evolved from the original concept. It discusses the determination of income and fuel costs and the possibilities for a relative and common European measure. It examines problems inherent in assessing fuel costs as a percentage of income and puts forward the arguments for a 'budget standard' approach. The paper illustrates how the size of the problem depends on the definition and chosen threshold and suggests advantages for a rating scale. It illustrates how the income composition and thresholds also govern the distribution of the target populations and the relative importance of the main causal factors, and examines the consequent policy implications. It explores the definition of vulnerable households and the importance of severity and questions whether the UK fuel poverty strategy is targeted at households least able to afford their fuel costs (as the name implies) or primarily those at risk from excess winter and summer mortality and morbidity. Finally, after examining the role of supplementary indicators, it looks at the opportunities for changing the definition and comments on the Government review of the definition and targets.

13/02536 Developing a database of energy use for historic dwellings in Bath, UK

Moran, F. *et al. Energy and Buildings*, 2012, 55, 218–226.

Historic dwellings in the UK make up to 20% of all homes. In the Georgian city of Bath this rises to 30%. These buildings are amongst the most poorly performing part of the English housing stock in energy use terms, with the lowest SAP rating and highest average annual CO_2 emissions. The legal aim to reduce CO_2 emissions of 80% by 2050 will involve all existing dwellings, including historic buildings. The degree to which proposals to retrofit the UK housing stock can reduce emissions depends on how much energy they currently use, what it is used for and how much CO_2 they emit. This paper establishes a benchmark of energy use and CO_2 emissions for historic dwellings in Bath. This permits comparison of their energy performance against other parts of the housing stock and will facilitate evaluation of potential retrofit adaptations.

13/02537 Development and testing of an automated building commissioning analysis tool (ABCAT)

Bynum, J. D. *et al. Energy and Buildings*, 2012, 55, 607–617.

Experience has shown that buildings on average may consume 20% more energy than required for occupant comfort which by one estimate leads to $18 billion wasted annually on energy costs in commercial buildings in the USA. Experience and large-scale studies of the benefits of commissioning have shown the effectiveness of these services in improving the energy efficiency of commercial buildings. While commissioning services do help reduce energy consumption and improve performance of buildings, the benefits of the commissioning tend to degrade over time. In order to prolong the benefits of commissioning, a prototype fault detection and diagnostic tool intended to aid in reducing excess energy consumption known as an automated building commissioning analysis tool (ABCAT) has been developed and tested. ABCAT is a first principles based whole building level top down tool which does not require the level of expertise and investment associated with detailed component level methods. ABCAT utilizes a calibrated mathematical model to predict energy consumption for given weather conditions. A detailed description of the methodology is presented along with testing results. Results from retrospective and live test case applications are presented where the tool was used to successfully identify significant energy consumption deviations.

13/02538 Development of a UK Centre for Efficient and Renewable Energy in Buildings (CEREB)

Day, A. *et al. Renewable Energy*, 2013, 49, 166–170.

The Centre for Efficient and Renewable Energy in Buildings (CEREB), is a pioneering new facility at London South Bank University. Created in partnership with City and Kingston Universities, CEREB is a unique resource for the teaching, research and demonstration of low carbon energy technologies in the built environment. The three partners are leaders in training and research in the built environment and the centre is at the forefront of low carbon building design. CEREB provides a high-quality teaching resource in sustainable energy technology and building design, construction and management. It also offers facilities to conduct research and to demonstrate specific sustainable energy technologies. CEREB is a unique urban-based showcase for low carbon energy technologies including photovoltaics, solar thermal, ground source heat pumps and wind power. Developed as a specially designed walk-through demonstration facility at roof level on LSBU's new K2 building, CEREB will provide a focus for work on improving skills in building services and energy. The new Centre will help fill the current skills gap on renewable and energy efficient technologies in order to meet the challenging carbon reduction targets set down in UK legislation.

13/02539 Domestic energy policy effects on the US biomass market

Whistance, W. *Biomass and Bioenergy*, 2012, 46, 133–144.

This study develops and applies a structural, partial-equilibrium model of United States biomass supply and demand. The aim is to examine the biomass price and expenditure effects of domestic biofuel policies. The results indicate that the cellulosic biofuel sub-mandate alone could increase biomass prices by an average of 50–100% over the baseline values. Biomass expenditures including those by biofuel producers increase by an average of 140% relative to the baseline. A sensitivity analysis focusing on supply response indicates that the results are fairly sensitive to the supply elasticity. This study contributes to the literature by providing policymakers and other energy policy stakeholders with a forward looking analysis of potential policy effects on the US biomass market.

13/02540 Economic and environmental costs of rural household energy consumption structures in Sameakki Meanchey district, Kampong Chhnang Province, Cambodia

San, V. *et al. Energy*, 2012, 48, (1), 484–491.

Clean energy development in rural areas in Cambodia plays an important role in developing the economics of the poor. This study was conducted to explore rural household energy consumption in Sammeakki Meanchey district in Kampong Chhnang Province and its impact on the economy and environment using a quantitative model. The results show that most households consume a variety of non-conventional energy sources, including traditional biomass (fuelwood, plant waste, etc.), kerosene and even LPG (liquefied petroleum gas). Biomass is used for cooking and boiling water, while rechargeable batteries are exclusively used for lighting and running home devices. The monthly economic cost under the current structure with electricity at US$33.23 is higher than the structure without electricity at US$19.11. However, the monthly environmental cost of the structure with electricity is lower than the structure without electricity which the environmental cost is the highest. Monthly cash payment for energy structure with fossil fuel dominating is placed in the middle. Clear differences in the total cost, environmental cost, and economic cost for households are found among the four substitutable structures. Both the environmental and economic costs are lower when biogas is used, so this structure should be promoted throughout the rural areas in Cambodia.

13/02541 Effects and mechanism of influence of China's resource tax reform: a regional perspective

Zhang, Z. *et al. Energy Economics*, 2013, 36, 676–685.

China's resource tax reform, beginning with Xinjiang as a pilot area in June 2010, marked a new stage in the progression of China's resource tax system. Based on the 2007 social accounting matrix (SAM) for Xinjiang, constructed by the authors, this paper takes a regional perspective on China's resource tax reform to quantitatively calculate its degree of influence and qualitatively analyse its mechanism of influence by adopting an energy computable general equilibrium model and a SAM price model. The results show that the main significance of the reform lies in bolstering local government finances rather than energy conservation or carbon reduction. This is because revenue will be transferred from resource enterprises and the central government to the local government, while simultaneously the low tax rate, narrow tax scope and unreasonable price mechanism will combine to prevent the reform from reaching its environmental goals. Promoting resource price mechanism reform and deepening resource tax reform will be two key elements of China's future energy strategies. Because resource enterprises will bear the increased burden caused by the reform, the degree of sectoral price increases will be limited; therefore, the fear that resource tax reform will push up inflation is unnecessary and should not be a barrier to reform.

13/02542 Energy consumption and income in Chinese provinces: heterogeneous panel causality analysis

Akkemik, K. A. *et al. Applied Energy*, 2012, 99, 445–454.

In recent times, energy production in China fell behind energy consumption. This poses important challenges for the rapidly growing Chinese economy. As a consequence, the causal relationship between energy consumption and gross domestic product (GDP) is an important empirical issue. This paper examines Granger causality between energy consumption and GDP in China using province-level data. The current paper extends the Granger causality analysis employed in previous studies by taking into account panel heterogeneity. Specifically, four different causal relationships are examined: homogeneous non-causality (HNC), homogeneous causality (HC), heterogeneous non-causality (HENC), and heterogeneous causality (HEC). HC and HNC hypotheses are rejected for causality in either direction, from GDP to energy or from energy to GDP, which implies that the panel made up of Chinese provinces is not homogeneous. Then, heterogeneous causality tests (HEC and HENC) are conducted for each province. For the causality running from GDP to energy, 19 provinces exhibit HEC and 11 provinces exhibit HENC. For the causality running from energy to GDP, 14 provinces exhibit HEC and 16 provinces exhibit HENC. The results suggest that the Chinese government should incorporate a regional perspective while formulating and implementing energy policies.

13/02543 Energy options for residential buildings assessment

Rezaie, B. *et al. Energy Conversion and Management*, 2013, 65, 637–646.

The building sector, as one of the major energy consumers, demands most of the energy research to assess different energy options from various aspects. In this paper, two similar residential buildings, with either low or high energy consumption patterns, are chosen as case studies. For these case studies, three different renewable energy technology and three different hybrid systems are designed for a specified size. Then, the environmental impact indices, renewable energy indices, and the renewable exergy indices have been estimated for every energy options. Results obtained show that the hybrid systems (without considering the economics factors) are superior and having top indices. The importance of the energy consumption patterns in buildings are proven by the indices. By cutting the energy consumption to about 40% the environment index would increase by more than twice (2.1). Utilization of the non-fossil fuels is one part of the solution to environmental problems while energy conservation being the other. It has been shown that the re-design of the energy consumption model is less complex but more achievable for buildings.

13/02544 Energy plus standard in buildings constructed by housing associations?

Stutterecker, W. and Blümel, E. *Energy*, 2012, 48, (1), 56–65.

In order to achieve national, European and international energy goals, energy efficiency strategies in the building sector have to be implemented. The passive house standard and low energy standards are already successfully established in single dwelling houses. These high performance standards are starting to penetrate into the sector of housing associations. A case study about an apartment building constructed by a housing association is presented here. It describes the monitoring concept and the results of the 1st year of monitoring. Depending on the definition of the zero energy building standard (extent of loads included in the balancing), the building could be classified as an energy plus building or as a building, which uses more energy, than is supplied by on-site generation. If the building's total energy use (including user specific loads) is defined as load, only 34.5% of these loads were provided by the net energy output of the PV system. If only the heating energy demand is defined as load, the PV system even yielded a surplus of 45.6% of the energy load.

13/02545 Existing building retrofits: methodology and state-of-the-art

Ma, Z. *et al. Energy and Buildings*, 2012, 55, 889–902.

Retrofitting of existing buildings offers significant opportunities for reducing global energy consumption and greenhouse gas emissions. This is being considered as one of main approaches to achieving sustainability in the built environment at relatively low cost and high uptake rates. Although there are a wide range of retrofit technologies readily available, methods to identify the most cost-effective retrofit measures for particular projects is still a major technical challenge. This paper provides a systematic approach to proper selection and identification of the best retrofit options for existing buildings. The generic building retrofit problem and key issues that are involved in building retrofit investment decisions are presented. Major retrofit activities are also briefly discussed, such as energy auditing, building performance assessment, quantification of energy benefits, economic analysis, risk assessment, and measurement and verification of energy savings, all of which are essential to the success of a building retrofit project. An overview of the research and development as well as application of the retrofit technologies in existing buildings is also provided. The aim of this work is to provide building researchers and practitioners with a better understanding of how to effectively conduct a building retrofit to promote energy conservation and sustainability.

13/02546 Functional form and aggregate energy demand elasticities: a nonparametric panel approach for 17 OECD countries

Karimu, A. and Brännlund, R. *Energy Economics*, 2013, 36, 19–27.

This paper studies whether the commonly used linear parametric model for estimating aggregate energy demand is the correct functional specification for the data generating process. Parametric and non-parametric econometric approaches to analysing aggregate energy demand data for 17 Organization for Economic Co-operation and Development (OECD) countries are used. The results from the non-parametric correct model specification test for the parametric model rejects the linear, log-linear and translog specifications. The non-parametric results indicate that the effect of the income variable is non-linear, while that of the price variable is linear but not constant. The non-parametric estimates for the price variable is relatively low, approximately −0.2.

13/02547 Identification and quantification of principal–agent problems affecting energy efficiency investments and use decisions in the trucking industry

Vernon, D. and Meier, A. *Energy Policy*, 2012, 49, 266–273.

Energy-related principal–agent (PA) problems cause inefficient combinations of investment, operating costs, and usage behaviour. The complex market structure of the trucking industry contributes to split incentives because entities responsible for investments in energy efficiency do not always pay fuel costs and drivers are often not rewarded for fuel-efficient operation. Some contractual relationships exist in the trucking industry that hinder responses to fuel price signals. Up to 91% of total trucking fuel consumption in the USA is affected by 'usage' PA problems, where the driver does not pay fuel costs and lacks incentive for fuel saving operation. Approximately 23% of trailers are exposed to an 'efficiency problem' when owners of rented trailers do not pay fuel costs and therefore have little incentive to invest in efficiency upgrades such as improved trailer aerodynamics and reduced tyre rolling resistance. This study shows that PA problems have the potential to significantly increase fuel consumption through avoided investments, insufficient maintenance, and fuel-wasting practices. Further research into the causes and effects of PA problems can shape policies to promote better alignment of costs and benefits, leading to reduced fuel use and carbon emissions.

13/02548 Impact of the lifespan of building external walls on greenhouse gas index

Mequignon, M. *et al. Building and Environment*, 2012, 59, 654–661.

The paper focuses on the assessment of greenhouse gas emissions produced by the walls of buildings according to their lifespan. These assessments take account of the construction, maintenance and end of life. The contribution of the utilization phase must be equivalent for all technical solutions for a given usage function. In the first part of the paper, the methodology is described by (1) considering a unit area of wall (i.e. 1 square metre), (2) determining a long service life, (3) choosing technical solutions in agreement with the specifications, (4) establishing the lifespan of each technical solution according to experts, (5) finding the corresponding greenhouse gas index from an appropriate database, and finally (6) modelling the evolution of these indicators with time. Several technical solutions (concrete, brick, stone, wood, aerated concrete) are considered and lifespans range from a few years to centuries. The results of this analysis suggest and quantify the important impact of lifespan on greenhouse gas emission indicators. For example, the best technical solution for a short lifetime can be the worst on a longer duration and vice versa. In the second part, since the lifespan of a product is very difficult to determine objectively, it is considered as a variable. The numerical results presented point out the need to revisit the current life cycle tools.

13/02549 Integrated resource planning for Iran: development of reference energy system, forecast, and long-term energy-environment plan

Amirnekooei, K. *et al. Energy*, 2012, 46, (1), 374–385.

The objectives of this study are to (i) develop a reference energy system and forecast of energy consumption (EC) for a 25-year period (2011–2035) for Iran and (ii) examine the effects of several demand and supply side management strategies on resource depletion and environmental emissions. A reference energy system is developed utilizing Iran energy balance data for 2009. Bottom-up analysis is performed using LEAP (long-range energy alternative planning) based on EC forecasted by two methods, namely, artificial neural network and Joel Darmstadter model. For demand-side management, four scenarios are examined: (a) replacement of incandescent lamps with compact fluorescent lamps (CFL), (b) utilization of electric stoves (ES) in place of natural gas (NG) fuelled stoves, (c) employment of coal power plants (CPP), and (d) applying all these scenarios together (ALL). On the supply side, the utilization of hydro-pump storage and employment of upgrading gas turbine plants to combined cycle ones are also considered for (a), (b), and (d) scenarios. The results show that applying CFL, ES, CPP, and ALL scenarios up to year 2035 results in crude oil and NG savings equivalent to 1.67, 1.24, 1.86, and 3.22 times Iran total primary crude oil and NG supply in 2009, respectively.

13/02550 Long term energy demand projection and potential for energy savings of Croatian tourism–catering trade sector

Irsag, B. *et al. Energy*, 2012, 48, (1), 398–405.

Today, tourism represents one of the backbones of Croatian economy and one of the main factors of its growth. Combined with catering trade sector, tourism represents a significant energy consumer that has the tendencies of future growth. Since services sector, which tourism–catering trade sector is a part of, is not yet well described regarding future energy balances it would be very interesting to see how could possible future growth in tourism influence energy consumption of the services sector in Croatia. Through this paper long-term energy demand projections of tourism–catering trade sector were studied with special emphasis on future growth of tourism in Croatia as well as different mechanisms that might lead to certain energy savings. Bottom-up approach was chosen as the most suitable one since it allows better quantification of different measures, technological or legal, that would influence future energy demand. Downside of this approach is extensive input data that is required to analyse and model future energy demand which is roughly divided into heating/cooling section and all other consumption. Results show that additional energy savings in the tourism–catering trade sector are possible if careful and rational demand side planning is in place.

13/02551 Mathematical modelling of embodied energy, greenhouse gases, waste, time–cost parameters of building projects: a review

Abanda, F. H. *et al. Building and Environment*, 2012, 59, 23–37.

The construction industry including its support industries is one of the highest consumers of natural resources. In the act of consumption of natural resources during construction processes, embodied energy and greenhouse gases are emitted which have adverse effects on the natural environment. Thus, recent studies have revealed a significant interest in the quantification of embodied energy and greenhouse gases in construction processes. Unfortunately, current interpretations and quantification procedures of embodied energy and greenhouse gases are quite unclear. More also, while greenhouse gas and embodied energy quantification models are so disaggregated, studies reveal their existence in isolation without any links to other important environmental/construction management variables such as waste, time and cost. The objectives of this study are to identify the gaps in the current computation models, to reveal the relationships between the identified models and to propose a framework towards developing an integrated model for measuring embodied energy, greenhouse gases, construction waste, time and cost. The contributions of this study are three-fold. Firstly, it provides the identification of the different models and variables, such that they can be used in computations, that can lead to consistent and comparable results. Secondly, the study investigates the relationships among embodied energy, greenhouse gases, construction waste, cost and time variables, that can facilitate the quantification process and hence potentially facilitate the engagement into low carbon building design by construction professionals. Lastly, the study lays the foundation for further research especially with regards to the integration of the different models and variables so that they can be measured simultaneously.

13/02552 Modelling fuel consumption in wheat production using artificial neural networks

Safa, M. and Samarasinghe, S. *Energy*, 2013, 49, (1), 337–343.

An artificial neural network (ANN) approach was used to model the fuel consumption of wheat production. This study was conducted over 35,300 ha of irrigated and dry land wheat fields in Canterbury, New Zealand in the 2007–2008 harvest year. From an extensive data collection involving 40 farms, the total fuel consumption in wheat production was estimated at 65.3 l/ha. On average, fuel consumption in tillage and harvesting was more than in other operations, at 29.6 l/ha (45%) and 18 l/ha (28%), respectively. The ANN model developed was capable of predicting fuel consumption in wheat production under different conditions using technical and social factors. This will help farmers find the best practice to reduce their expenditure, with minimum income reduction. This study investigated the potential for using ANN to forecast fuel consumption, as compared to traditional regression models. After examining more than 140 different factors, eight were selected as influential input into the model. The final neural network model can predict fuel consumption based on farm conditions (size of wheat area and number of sheep), farmers' social considerations (level of education), farm operation (number of passes of plough), machinery condition (age of sprayer) and farm inputs (P, herbicide and insecticide consumption) in arable farms in Canterbury with an error margin of ±8% (±5.6 l/ha).

13/02553 Obsolete or resurgent? The International Energy Agency in a changing global landscape

Van de Graaf, T. *Energy Policy*, 2012, 48, 233–241.

Founded in response to the 1973 oil shock, the International Energy Agency (IEA) is arguably still the most important multilateral organization for energy-importing countries. Yet, the global geopolitical landscape has changed considerably since the IEA's creation. The rise of new energy consumers, new energy-related challenges and new international energy forums prompt a rethink of the agency's current role and institutional design. This paper seeks to contribute to the recent debate on the future role of the IEA by examining specific drivers, avenues and constraints for institutional reform. The method used is SWOT analysis, which allows one to summarize the key factors emanating from an assessment of an organization's internal characteristics (strengths and weaknesses) and its external environment (opportunities and threats). Building on this SWOT analysis, the article formulates a strategy for the IEA to remain the focal point in global energy governance. Key elements of this strategy include: stronger engagement with new consumers, rapprochement with OPEC, becoming a leading voice in the energy transition, and changing the agency's internal governance practices.

13/02554 Potential options to greenize energy systems

Dincer, I. and Zamfirescu, C. *Energy*, 2012, 46, (1), 5–15.

This study introduces a new thermodynamic concept of greenizing energy systems and propose a new greenization factor which is defined as the amount of environmental impact reduction by the system greenized divided by the reference environmental impact for the original (reference) case. A greenization factor of 1 indicates that the system is fully greenized case in which its environmental impact is zero or minimal. The greenization options of energy systems are studied extensively for an actual coal-fired power plant in Ontario. Multiple case studies are presented under various greenization criteria. The greenization factors and sustainability indexes for each option are determined and presented comparatively. The results can be extended to other energy systems, processes and applications (e.g. fossil fuel-based power plants and transportation vehicles) for assessment purposes.

13/02555 Strategic energy planning within local authorities in the UK: a study of the city of Leeds

Bale, C. S. E. *et al. Energy Policy*, 2012, 48, 242–251.

This paper considers the development of a strategic energy body in a local authority in the UK and looks at the perceived need for, and possible roles of, such a body. Historically, energy provision and management has not usually been a strategic priority for UK local authorities. Yet energy considerations are implicit in key local authority responsibilities such as transport, waste management, planning, and the provision of housing services. In addition, recent UK central government policies support the move to localism and provide incentives for low-carbon energy generation. A study was undertaken to assess the potential (including both the perceived benefits and actual capacity to deliver) for Leeds City Council to develop a strategic body to execute delivery of city-level energy decision-making. This study examines the perceived benefits to a range of main stakeholders, using data drawn from interviews with managers responsible for low-carbon and renewable energy projects across the city. The case study suggests that there are financial, structural and (perhaps to a lesser extent) cultural barriers to the implementation of a strategic energy body. However, in the light of recent measures by the UK government to enable local authorities to benefit financially from local energy projects, the present work suggests that a strategic energy body could, with the political will and some modest initial funding, become self-financing in the medium term by generating revenue through a single ESCo or multiple 'arm's-length' ESCos, in order to provide sufficient funds for developing other project streams. Most of these findings appear to be applicable generically to local authorities, particularly those that are responsible for cities or other major urban conurbations. Many local authorities are setting local climate change targets, and a strategic energy body would provide a path to facilitating the interventions needed to achieve these targets. The national policy regime does not currently incentivize local authorities to take a strategic approach to energy; rather, funding is provided for separate initiatives and for meeting separate targets. However, the strategic energy function at a local level conforms to the foundations of the current government's localism and sustainable energy policy areas. The authors argue that, if funds were instead partly channelled to providing for strategic energy planning provision at a local or regional level, efficiencies and, therefore, enhanced outcomes could be achieved. This could be achieved through local enterprise partnerships, with funding from national and EU funding schemes. It is not clear at this stage how Local Enterprise Partnerships will evolve, but incorporation of a strategic energy facility would provide the benefits outlined earlier and would be an appropriate mechanism for engaging with public sector partners. Although national government can create a climate favourable to local strategic approaches to energy, only if a local authority has clear leadership and ambition in the energy arena will a strategic energy function be implemented and the associated benefits attained.

13/02556 Target for national carbon intensity of energy by 2050: a case study of Poland's energy system

Budzianowski, W. M. *Energy*, 2012, 46, (1), 575–581.

The article analyses CO_2 emissions from fossil fuel combustion and provides tools for estimating the target for national carbon intensity of energy by 2050. A case study of the energy system of Poland is presented. It is revealed that if carbon emissions are to be reduced by 80% from 1990 to 2050, the energy mix of Poland will require significant structural changes. This will be however challenging, because Poland has a huge coal sector and limited potential for harvesting renewable energy sources, excluding only biomass. The carbon intensity of primary energy would have to be reduced in Poland from $20\,g\,C\,MJ^{-1}$ in 2009 to about $4.1\,g\,C\,MJ^{-1}$ in 2050 (including LULUCF). Further, the study suggests the national energy mix suitable for achieving this energy decarbonization target. It is found that a significant share of coal/peat can be retained only when CCS is applied to all fossil fuel-fired power plants and to large-scale industries. Besides, the share of biomass, other renewables and optionally nuclear energy must be significantly increased which will be both costly and technologically challenging. Further, deployment of carbon negative bioenergy as well as CO_2 recycling are suggested as promising energy decarbonization options.

13/02557 The causal relationship between energy use and economic growth in Switzerland

Baranzini, A. *et al. Energy Economics*, 2013, 36, 464–470.

This paper investigates the relationships between energy consumption and economic growth in Switzerland over the period 1950–2010. The authors apply bounds testing techniques to different energy types separately. Robustness tests are performed by including additional variables and restricting the analysis to the period after 1970. The results show that there exist robust long-run relationships going from real gross domestic product (GDP) toward heating oil and electricity consumption. The relationship between heating oil and GDP is in fact bidirectional, although weaker from heating oil toward GDP than in the reverse direction. When investigating the period 1970–2010 only, the estimate of the long-run income elasticity of electricity consumption loses statistical significance and that for heating oil becomes negative. Those results imply a possible decoupling between GDP growth and energy consumption, so that energy conservation policies are not necessarily expected to have a negative impact on Swiss economic growth.

13/02558 The development of low-carbon towns in China: concepts and practices

Li, Z. *et al. Energy*, 2012, 47, (1), 590–599.

A new concept of 'low-carbon towns' (LCTs) has emerged in the urban planning and development of China in recent years to face the challenge of global climate change. This paper presents the current status, basic concepts, and town practices for the development of LCTs in China. China has strong driving forces to develop LCTs, which come from a central government policy, international cooperation, and the self-motivation of regional governments. Thus, there are already many excellent town practices in place. However, different types of towns have different areas of focus in their LCT-related programs and barriers. The development of LCTs has multiple objectives beyond the reduction of CO_2 emissions, including economic development and the reduction of conventional pollutants; hence, the development of LCTs in China must pursue multiple benefits while reducing CO_2 emissions. Although there is still a long way to go to control the absolute CO_2 emissions for Chinese towns, the development of LCTs in China must aim toward a low-carbon economy and society and realize a smooth transition to a sustainable future that emphasizes minimum accumulated CO_2 emissions over the life cycle of towns. The main concepts for the development of LCTs include economic, social, layout, technology, and reuse approaches. These approaches should be integrated to develop LCTs, even though the emphasis may be different for each specific town. Currently, Chinese towns are already focusing considerable on technology and reuse approaches. However, economic, social, and layout approaches are also essential to realize a low-carbon economy and society in the future, and these approaches should receive more emphasis in the development of LCTs.

13/02559 The evolution of European passenger car characteristics 2000–2010 and its effects on real-world CO_2 emissions and CO_2 reduction policy

Fontaras, G. and Dilara, P. *Energy Policy*, 2012, 49, 719–730.

The European passenger-car certification test constitutes the basis for implementation and progress monitoring of the current CO_2 abatement policy. The certification test is performed over a single driving cycle (New European Driving Cycle, NEDC). The dynamics of NEDC and the fact that it does not account for other factors results in CO_2 emissions which are non-representative of real-world performance. Using available data from the CO_2 monitoring database and literature and employing simple vehicle dynamics model and stochastic techniques, this paper attempts to calculate the average gasoline and diesel passenger-car characteristics, investigate how the evolution of certain vehicle characteristics affects real world vehicle performance and to combine the above in order to evaluate the progress in terms of real world emissions and possible correction of existing emission factors. The analysis reveals that reductions over NEDC are generally reflected over real world. There were indications particularly for diesel vehicles that the NEDC–real world CO_2 emissions gap gradually widens and that existing emission factors should be amended accordingly. Currently this difference between certification and real world emission is estimated between 20% and 25%. The benefit of diesel vehicles compared to their gasoline equivalents in terms of CO_2 emissions appears to reduce.

13/02560 The impact of more efficient but larger new passenger cars on energy consumption in EU-15 countries

Ajanovic, A. *et al. Energy*, 2012, 48, (1), 346–355.

The core objective of this paper is to analyse the impact of changes in fuel intensity and car size on energy demand of passenger cars in the European Union (EU)-15 countries. Of special relevance in this context is how the rebound effect due to the change in car fuel intensity and car size (average engine power) affects the energy conservation effect. Lower fuel intensity reduces the cost of car travel, and may lead to further growth in vehicle-kilometres driven and car size, while higher fuel prices may offset this effect to some extent. The major conclusion is that for passenger cars policies that only strive for efficiency improvements will have very limited success. It is necessary to introduce proper additional fuel taxes (to curb the increase in vehicle-kilometres) and size-dependent registration taxes (to avoid excessive increases in car size) to finally harvest the full societal benefits of better car efficiency.

13/02561 U.S. household energy consumption and intensity trends: a decomposition approach

Hojjati, B. and Wade, S. H. *Energy Policy*, 2012, 48, 304–314.

Concerns over impacts from US energy use on the environment, the economy and the national security warrant an understanding of the key drivers of energy consumption. This paper focuses on decomposing US household energy consumption changes into several factors that have affected its growth. The interval analysed is based on household surveys conducted by the US Energy Information Administration from 1980 through 2005. Drivers of total household energy consumption, total household electricity consumption and natural gas use for space heating are analysed and contrasted. While not definitive, sub-period analyses split at 1990, show greater reductions in energy intensity in the later sub-period and provide *prima facie* evidence of the efficacy of US efforts to promote energy efficiency through various standards and programmes.

13/02562 Understanding energy consumption behavior for future demand response strategy development

Vassileva, I. *et al. Energy*, 2012, 46, (1), 94–100.

Encouraging consumers to use less electricity through information is essential for sustainable use of energy and demand response is indeed a key component of the smart grids concept. The aim with this study is to understand differences between consumer categories and what this could mean, e.g. to develop effective demand response measures. In-depth analyses of answers from a questionnaire sent out to 2000 households, contribute to a better understanding of Swedish households' energy-related behaviour. The households have been provided with a website enabling them to check their daily electricity consumption compared to previous months/years and even get advice and tips on how to reduce electricity consumption. The results show clear differences in the response rates from different type of residence, different income areas of the city and in the most preferred ways of receiving information-feedback. The web-based feedback, provided by the local energy company, received more visits (and more frequently) from respondents living in houses than from apartments. The analysis of the answers raises questions about the effectiveness of using only one tool of providing energy consumption information to the customers (website, in this case) and stresses the importance of applying an individual approach to different energy users.

13/02563 Volatility spillover between oil and agricultural commodity markets

Nazlioglu, S. *et al. Energy Economics*, 2013, 36, 658–665.

This study examines volatility transmission between oil and selected agricultural commodity prices (wheat, corn, soybeans, and sugar). The authors apply the newly developed causality in variance test and impulse response functions to daily data from 1 January 1986 to 21 March 2011. In order to identify the impact of the food price crisis, the data are divided into two sub-periods: the pre-crisis period (1 January 1986 to 31 December 2005) and the post-crisis period (1 January 2006 to 21 March 2011). The variance causality test shows that while there is no risk transmission between oil and agricultural commodity markets in the pre-crisis period, oil market volatility spills on the agricultural markets – with the exception of sugar – in the post-crisis period. The impulse response analysis also indicates that a shock to oil price volatility is transmitted to agricultural markets only in the post-crisis period. This paper thereby shows that the dynamics of volatility transmission changes significantly following the food price crisis. After the crisis, risk transmission emerges as another dimension of the dynamic interrelationships between energy and agricultural markets.

Energy conservation

13/02564 A methodology for economic efficient design of net zero energy buildings

Kapsalaki, M. *et al. Energy and Buildings*, 2012, 55, 765–778.

This work developed a methodology and an associated calculation platform in order to identify the economic efficient design solutions for residential net zero energy building (NZEB) design considering the influence of the local climate, the endogenous energy resources and the local economic conditions. One case study of a detached house for three climates was analysed with the tool developed in order to gain insights on the economic space of NZEB solutions and the influence of the climatic context. A methodology for assisting the choice of economically efficient NZEB solutions from the early design stage is now available. Its use in practice may be of great relevance as the results showed that the differences between an economically efficient and economically inefficient NZEB can be over three times both in terms of initial and life cycle cost.

13/02565 A simplified method to estimate the energy-saving potentials of frequent construction and demolition process in China

Fu, F. *et al. Energy*, 2013, 49, (1), 316–322.

This study proposes a simplified method and build a model accordingly for estimating the energy-saving potentials of building construction and demolition with the consideration of China's rapid growth of building construction and its short actual lifespan of buildings. To demonstrate the practicability of the proposed method and model, an illustrative case study is developed to estimate the energy-saving potentials from residential building sector in China. The results show that a considerable amount of energy-saving potentials can be captured from now until 2020, 2030, or 2050 by smooth implementation of either controlling the growth in demand for the per capita residential building floor area or extending the actual lifespan of the residential buildings in China. Through this study, the authors fill the gap, in terms of method and model, of supporting the further improvement of China's existing energy conservation policies.

13/02566 Alternatives to *Sedum* on green roofs: can broad leaf perennial plants offer better 'cooling service'?

Blanusa, T. *et al. Building and Environment*, 2012, 59, 99–106.

Green roof plants alter the microclimate of building roofs and may improve roof insulation. They act by providing cooling by shading, but also through transpiration of water through their stomata. However, leaf surfaces can become warmer when plants close the stomata and decrease water loss in response to drying substrate (typically associated with green roofs during summers), also reducing transpirational cooling. By using a range of contrasting plant types (*Sedum* mix – an industry green roof 'standard', *Stachys byzantina*, *Bergenia cordifolia* and *Hedera hibernica*) the authors tested the hypothesis that plants differ in their 'cooling potential'. They firstly examined how leaf morphology influenced leaf temperature and how drying substrate altered that response. Secondly, they investigated the relationship between leaf surface temperatures and the air temperatures immediately above the canopies (i.e. potential to provide aerial cooling). Finally the authors measured how the plant type influenced the substrate temperature below the canopy (i.e. potential for building cooling). In the experiments *Stachys* outperformed the other species in terms of leaf surface cooling (even in drying substrate, e.g. 5 °C cooler compared with *Sedum*), substrate cooling beneath its canopy (up to 12 °C) and even – during short intervals over hottest still periods – the air above the canopy (up to 1 °C, when soil moisture was not limited). The authors suggest that the choice of plant species on green roofs should *not* be entirely dictated by what survives on the shallow substrates of extensive systems, but consideration should be given to supporting those species providing the greatest eco-system service potential.

13/02567 An approach to energy saving assessment of solar assisted heat pumps for swimming pool water heating

Tagliafico, L. A. *et al. Energy and Buildings*, 2012, 55, 833–840.

A steady state off-design model of a water solar assisted heat pump (W-SAHP) and the results of monthly based averaged simulations are presented. The W-SAHP system is arranged with a commercial water-to-water heat pump, coupled with unglazed flat plate solar collectors. The study is purposely developed for swimming pools, however most of the analysis criteria and outcomes are valid for any building (user) having hot water needs. Calculations are made for given thermal load and user operating temperatures with reference to the climatic data of all Italian municipalities, that is degree days (DD) in the range from 700 to 3000, altitude from 0 to 1500 m (above sea level), and latitude from 36.5°N to 46.3°N. The primary energy saving capability of the W-SAHP solution, compared to a traditional gas-boiler plant, is analysed as a function of the DD index of each site. Despite the large spread of climatic and altitude data, the results show that the W-SAHP performance is usually well correlated to DD, which can therefore be assumed as the main independent variable for the energy saving assessment of these systems, and make the results easily extended to other possible geographical locations.

13/02568 Analysis of energy savings in a supermarket refrigeration/HVAC system

Bahman, A. *et al. Applied Energy*, 2012, 98, 11–21.

The paper analyses refrigeration/(heating, ventilation and air conditioning systems) HVAC system energy consumption in a typical food retail store to study the effects of indoor space conditions. Refrigerated display cases are normally rated at a store environment of 24 °C (75 °F) and a relative humidity of 55%. If the store can be maintained at lower relative humidity, significant quantities of refrigeration energy, defrost energy, and anti-sweat heater energy can be saved. Calculations were done for a typical day in a standard store for each month of the year using the climate data for Tampa, Florida. This results in a 24 h variation in the store relative humidity. Using these hourly values of relative humidity for a typical 24 h day, the store relative humidity distribution was calculated for a full year. The annual average supermarket relative humidity was found to be 51.1%. It is shown that for a 5% reduction in store relative humidity, the display case refrigeration load is reduced by 9.25%, and that results in total store energy load reduction of 4.84%. The results were compared to available experimental data and found to have a good agreement.

13/02569 Design and analysis of a high-intensity LED lighting module for underwater illumination

Shen, S. C. *et al. Applied Ocean Research*, 2013, 39, 89–96.

Replacing traditional light sources with light-emitting diode (LED) light modules is a global trend, especially for underwater illumination. The light intensity is dispersed evenly at all emission angles in traditional underwater light sources that use the radiative transfer model, resulting in the inclusion of scattering factors in the attenuation coefficient. The high directionality of LED light source modules causes the light intensity transfer in water to vary according to varying emission angles. This renders traditional underwater optical transfer theory irrelevant as an underwater LED light module design reference. Therefore, this study constructs an underwater LED light source transfer model using the light-field average cosine and the light transfer scattering probability method, and imports the LED luminous intensity distribution curve (LIDC) and axial luminous intensity. Experimental results showed that the illumination intensity of the underwater LED illumination module was less than 10% of the simulation. Therefore, this design method can be used to design the required illumination light modules for different underwater environments. Finally, the LED light module has been used for under water fish attractor lighting and enhanced the illumination zone efficiency (m^3 per watt) of 81% compared to the traditional high intensity discharge underwater fish attractor lamp.

13/02570 Energy efficient museum buildings

Mueller, H. F. O. *Renewable Energy*, 2013, 49, 232–236.

Museum buildings perform ambitious demands for sound conditions of exhibits and comfort of visitors. There is a narrow allowance for room temperature and relative humidity, which has to be maintained for varying situations of weather and occupancy. Lighting has to assure an excellent visual performance but to avoid deterioration of exhibits. Energy consumption can be kept extremely low contrariwise. Several high quality and low energy museum buildings could be realized recently by utilization of energy efficient measures and renewable energies. Outstanding pieces of architecture, e.g. Kolumba Art Museum, Cologne (architect P. Zumthor), Emil-Schumacher-Museum, Hagen (architect M. Lindemann), are presented and integrated advanced technologies like thermal active room surfaces, low air change ventilation, geothermal heating and cooling, and controlled daylighting are explained.

13/02571 Energy reduction measures in agricultural greenhouses heating: envelope, systems and solar energy collection

Fabrizio, E. *Energy and Buildings*, 2012, 53, 57–63.

While a great reduction of the energy demand for the environmental control of civil buildings has been reached in recent years, still a great potential of energy savings lies in other sectors like the one of agricultural production. The scope of this paper is to investigate the energy performance of some of the recent envelope and systems technologies that best can contribute to a great reduction of the energy demand for the climatic control of a greenhouse for intensive crop production. This paper concentrates on three aspects: the use of polycarbonate hollow sheets to reduce the thermal transmittance of the glazing, the application of polypropylene sheets as a basal heating system and the solar energy capture by means of low cost plastic solar collectors. A tunnel greenhouse for basil production of 40 m of length and 10 m of width was considered as a case study and modelled within the EnergyPlus simulation software. The climate locations that were considered refer to the north-west of Italy. The results show that savings of the order of 30% can be achieved by using more insulated transparent materials. On the contrary, the application of the solar collectors still remains problematic because of the large land use and lower global efficiencies.

13/02572 Energy saving and environmental resources potentials: toward new methods of building design

Chesné, L. *et al. Building and Environment*, 2012, 58, 199–207.

With the current issues concerning the management of finite energy resources and the potential savings in the building sector, reducing building energy consumption is a key point. Up to now, efforts have been focused on insulation to separate the inner ambiance from the fluctuation of the outside air temperature. Assuming that insulating a building might not be the best solution to exploit the free renewable sources of its environment (outside air temperature, sky temperature, solar radiation), a first identification step has been carried out to determine which sources should be exploited. Building energy simulations have been carried out, including several insulation levels and climatic conditions. Then, indicators have been defined in order to quantify the ability of the previous sources to cover the energy needs and the possibility for the building to exploit them. Finally, the previous indicators have been applied to the different configurations of buildings. The study shows that whatever the climate or the insulation level is, some resources such as the sun and the sky are not enough exploited, although some could entirely cover the building needs at each time step (case of the sky). When it is not possible, the paper proposes a method to evaluate the remaining needs and the sizing of a supplementary heating/cooling system.

13/02573 Energy saving potential of low temperature hot water system based on air source absorption heat pump

Li, X. *et al. Applied Thermal Engineering*, 2012, 48, 317–324.

Boilers are widely used to generate low temperature hot water for heating and domestic hot water. In order to improve the efficiency and decrease the emission of pollution in the process of producing low temperature hot water, a heating system based on air source absorption heat pump (ASAHP) is proposed. A simplified model of the proposed system is built based on the heat and mass balance. The model is verified by comparing the predicted results with those from a previous reference. The performances of ASAHP using H_2O/LiBr and NH_3/$LiNO_3$ as working fluids are simulated at different air temperatures. Based on the simulated performance, energy saving potential of the proposed system applied in four typical Chinese cities is analysed. The results show that the proposed system can provide energy saving rates of 18%, 28.5%, 37% and 42% in Shenyang, Beijing, Shanghai and Guangzhou respectively, showing great potentials in future applications of low temperature hot water.

13/02574 Energy saving study on a large steel plant by total site based pinch technology

Matsuda, K. *et al. Applied Thermal Engineering*, 2012, 43, 14–19.

The total site approach using a 'total site profile (TSP) analysis' (based on pinch technology) was applied to a large-scale steel plant. And it was confirmed, despite the very high efficiency of the individual process systems of the plant, that there would be a huge energy saving potential by adopting this approach. It became apparent that the available pinch technology tools and techniques lend themselves very well to the analysis of a steel plant. The heat (thermal energy) under 300 °C has previously not been well utilized in steel plants. But TSP analysis was able to identify the distribution and the quantity of such heat, from which energy saving plans could be developed.

13/02575 Exergetic cost analysis and sustainability assessment of various low exergy heating systems

Balta, M. T. *Energy and Buildings*, 2012, 55, 721–727.

This study deals with energy/exergy, exergy cost analyses and sustainability assessment of a low exergy heating system. In this study, an indoor sports hall with a volume of about 28,180 m^3 and a floor area of 2366 m^2 is considered as a case study. In this context, three different heating options are investigated, namely, (i) a conventional boiler, (ii) a condensing boiler and (iii) an air heat pump as driven by fuel-oil, natural gas and electricity, respectively. In this regard, an energy and exergy analysis is employed to assess their performances and compare them through energy and exergy efficiencies and sustainability index. Also, total exergy costs based on the considered systems with three different fuels are determined and compared with each other. Overall exergy efficiencies of the heating systems are found to be 2.10%, 2.33% and 2.42% while their corresponding sustainability index values of the analysed cases are calculated to be 1.021, 1.024 and 1.025 for cases 1–3, respectively. Total exergy costs of the considered systems are obtained to be $C_{\text{case1}} > C_{\text{case3}} > C_{\text{case2}}$. Based on the exergy cost analysis results, the most cost effective system is case 2.

13/02576 Gaussian process modeling for measurement and verification of building energy savings

Heo, Y. and Zavala, V. M. *Energy and Buildings*, 2012, 53, 7–18.

This study presents a Gaussian process (GP) modelling framework to determine energy savings and uncertainty levels in measurement and verification (M&V) practices. Existing M&V guidelines provide savings calculation procedures based on linear regression techniques that are limited in their predictive and uncertainty estimation capabilities. The authors demonstrate that, unlike linear regression, GP models can capture complex non-linear and multivariable interactions as well as multi-resolution trends of energy behaviour. In addition, because GP models are developed under a Bayesian setting, they can capture different sources of uncertainty in a more systematic way. The authors demonstrate that these capabilities can ultimately lead to significantly less expensive M&V practices. The developments are illustrated using simulated and real data settings.

13/02577 How to save energy to reach a balance between production and consumption of heat, electricity and fuels for vehicles

Dahlquist, E. *et al. Energy*, 2012, 46, (1), 16–20.

There is a potential to utilize a significant amount of renewable energy in Sweden and European Union (EU). Biomass can fulfil some 8500–12,500 TW h/y in EU, while the total utilization was 16,084 TW h/y 2009. Even though there is a significant amount of wind power, hydro power and potentially also solar power, it is still more economical to reduce the consumption of heat, electricity and fuels for vehicles. Saving a kWh is normally cheaper than to producing one. In this paper different opportunities for saving energy are discussed. This includes manufacturing industries, process industries, power plants and energy systems including distribution of power and smart grids, food production and transportation. There is also a major potential to save energy in buildings, both in the north where it is cold, and in the south where it can be very hot during the summer. Technical solutions as well as economic incentives are discussed. Environmental aspects are addressed, so that the solutions will be sustainable in the long term.

13/02578 Indoor thermal conditions and the potential of energy conservation of naturally ventilated rooms in summer, China

Zhong, K. *et al. Energy and Buildings*, 2012, 55, 183–188.

The indoor temperature and humidity of four cities which are located in different climatic zones in China were monitored continuously in summer. The results show that the indoor air temperatures varied in narrow bands in the cities and the indoor thermal conditions were far from the ASHRAE 55–92 summer comfort zone during most of the measuring period. The indoor thermal environment of naturally ventilated rooms of residential buildings in the four cities was evaluated by using the predicted mean vote (PMV) model and the adaptive comfort model (ACM). The difference of thermal satisfaction between the two results was analysed and discussed, and the potential of energy conservation was estimated by applying the ACM. The results show that even if energy consumption of dehumidification under humid climatic conditions is taken into consideration, when ACM is employed to optimize the operative temperature of the ventilation systems with the occupants maintaining control of the indoor thermal environment, the potential of energy conservation can be roughly more than 20% over the whole summer season in the four cities.

13/02579 Retrofitting using a dynamic envelope to ensure thermal comfort, energy savings and low environmental impact in Mediterranean climates

Stazi, F. *et al. Energy and Buildings*, 2012, 54, 350–362.

The paper presents an experimental and analytic study on multi-storey residential buildings without thermal insulation that were constructed before the introduction of energy saving standards (Italian Law 373/1976). Several activities were carried out to identify the optimal retrofit in terms of comfort, energy consumption and environmental impact: typological analysis of 70 buildings in the province of Macerata (central Italy) and energy analysis of representative case studies; monitoring of a selected case study during summer and winter; thermal simulation of the building in dynamic conditions with EnergyPlus software and calibration of the virtual model by comparison with experimental results; parametric analyses to predict the effect of various retrofit solutions on comfort and energy consumption; environmental impact on the different solutions. It was possible to identify the optimal retrofit solutions for the external vertical and horizontal envelopes. The study showed that the most effective strategy is the insulation of the external vertical wall. The introduction of an external ventilated coating was found to be the optimal solution in a temperate climate.

13/02580 The impact of place-based affiliation networks on energy conservation: an holistic model that integrates the influence of buildings, residents and the neighborhood context

Xu, X. *et al. Energy and Buildings*, 2012, 55, 637–646.

Models that consider, separately, the energy use of networks of buildings and networks of building occupants have been explored in existing literature toward the goal of understanding the role of building networks or occupant networks on building energy conservation. Yet, the neighbourhood surrounding buildings and their occupants can also have an influence on energy consumption patterns. Thus, the inclusion of this influence is important in an holistic evaluation of the built environment for aggregate energy performance. The authors developed an integrated, inter-building model comprised of a building network, an occupant social network, and the surrounding neighbourhood facilities, to conduct a three-stage prediction of energy conservation potential for an assumed urban residential block. They inferred utilization of neighbourhood facilities from US Census demographic data and then applied affiliation network theory to deduce inter-building occupant affiliation networks, and thus predict the potential spread of energy conservation that might be achieved via a combination of social networks and eco-feedback systems for the assumed block. The model results show that eco-feedback systems that leverage place-based social networks might lead to improvements in energy efficiency performance at the inter-building level that are comparable to efficiencies gained through typical building retrofits.

17 ENERGY CONVERSION AND RECYCLING

13/02581 A thermodynamic analysis of high temperature gas-cooled reactors for optimal waste heat recovery and hydrogen production

Li, P.-J. *et al. Applied Energy*, 2012, 99, 183–191.

In this study the concept of generalized cogeneration has been employed to the analysis of the effective heat recovery from the high temperature gas-cooled reactor (HTGR). Brayton cycle is used as a topping cycle for HTGR with helium as the working fluid. HTR-10 and VHTR, having different power levels of HTGR, have been applied in the present study. The paper investigates the optimal strategy of the heat recovery, which combines the bottoming cycles and the parameters such as the select of different working fluids and the ambient temperatures. The heat recovery has integrated the organic Rankine cycle (ORC) using the fluids, such as alkane and benzene to perform the thermodynamic analysis. The total efficiency could be increased by 13.57% and 3.12% for HTR-10 and VHTR, respectively. Brayton cycle has been employed in the heat recovery for the iodine–sulfur (IS) hydrogen production process of VHTR by integrating the intermediate cooling process with the recuperator. When the sulfur trioxide (SO_3) decomposition temperature is the lowest and the efficiency of the power conversion from hydrogen is assumed 0.6, the total thermal efficiency will be increased from 3.12% to 8.60%.

13/02582 Ammonia–water cogeneration cycle for utilizing waste heat from the GT-MHR plant

Zare, V. *et al. Applied Thermal Engineering*, 2012, 48, 176–185.

A combined cycle is proposed in which the waste heat from a gas turbine-modular helium reactor (GT-MHR) is utilized by an ammonia–water mixture (AWM) cycle to produce cooling and additional power. The AWM cycle is a combination of the Kalina and an absorption refrigeration cycles and has been referred to as the Goswami cycle in the literature. A detailed thermodynamic analysis is carried out for the proposed combined cycle and the effects of some important parameters such as; the compressor pressure ratio, the turbine inlet temperature, the pump pressure ratio and the boiler temperature on the combined cycle performance are investigated. The cycle performance is also optimized based on the first and second laws of thermodynamics. It is found that, at nearly optimum conditions, the energy utilization and second law efficiencies of the combined cycle are about 9–15% and 4–10% higher than those of the GT-MHR cycle, respectively. It is also concluded that superheating the ammonia vapour at the turbine entry results in a decrease of the combined cycle efficiency and output cooling.

13/02583 Analysis of vehicle exhaust waste heat recovery potential using a Rankine cycle

Domingues, A. *et al. Energy*, 2013, 49, (1), 71–85.

This study evaluates the vehicle exhaust waste heat recovery (WHR) potential using a Rankine cycle (RC). To this end, both a RC thermodynamic model and a heat exchanger model have been developed. Both models use as input, experimental data obtained from a vehicle tested on a chassis dynamometer. The thermodynamic analysis was performed for water, R123 and R245fa and revealed the advantage of using water as the working fluid in applications of thermal recovery from exhaust gases of vehicles equipped with a spark-ignition engine. Moreover, the heat exchanger effectiveness for the organic working fluids R123 and R245fa is higher than that for the water and, consequently, they can also be considered appropriate for use in vehicle WHR applications through RCs when the exhaust gas temperatures are relatively low. For an ideal heat exchanger, the simulations revealed increases in the internal combustion engine thermal and vehicle mechanical efficiencies of 1.4–3.52% and 10.16–15.95%, respectively, while for a shell and tube heat exchanger, the simulations showed an increase of 0.85–1.2% in the thermal efficiency and an increase of 2.64–6.96% in the mechanical efficiency for an evaporating pressure of 2 MPa. The results confirm the advantages of using the thermal energy contained in the vehicle exhaust gases through RCs. Furthermore, the present analysis demonstrates that improved evaporator designs and appropriate expander devices allowing for higher evaporating pressures are required to obtain the maximum WHR potential from vehicle RC systems.

13/02584 Application of a low pressure economizer for waste heat recovery from the exhaust flue gas in a 600 MW power plant

Wang, C. *et al. Energy*, 2012, 48, (1), 196–202.

This paper presents a case study of recovering the waste heat of the exhaust flue gas before entering a flue gas desulfurizer (FGD) in a 600 MW power plant. This waste heat can be recovered by installing a low pressure economizer (LPE) to heat the condensed water which can save the steam extracted from the steam turbine for heating the condensed water and then extra work can be obtained. The energy and water savings and the reduction of CO_2 emission resulted from the LPE installation are assessed for three cases in a 600 MW coal-fired power plant with wet stack. Serpentine pipes with quadrate finned extensions are selected for the LPE heat exchanger which has an overall coefficient of heat transfer of $37\,W/m^2{\cdot}K$ and the static pressure loss of 781 Pa in the optimized case. Analysis results show that it is feasible to install LPEs in the exhaust flue gas system between the pressurizing fan and the FGD, which has little negative impacts on the unit. The benefits generated include saving of standard coal equivalent (SCE) at 2–4 g/(kW·h) and saving of water at 25–35 t/h under full load operation with corresponding reduction of CO_2 emission.

13/02585 Applying analytic network process to evaluate the optimal recycling strategy in upstream of solar energy industry

Shiue, Y.-C. and Lin, C.-Y. *Energy and Buildings*, 2012, 54, 266–277.

This research presents an evaluation model to evaluate the various recycling strategies to obtain the optimal recycling collection strategy in the upstream of the solar energy industry (SEI). The recycling process includes three major stages: (1) collection, (2) inspection, and (3) process. The proposed model combines the benefits, opportunities, costs and risks and balance scorecard model. First, the evaluation model establishes a network with four perspectives, 20 indicators, and four strategies. Next, the analytic network process is applied to the model to determine the relative weights of the evaluative criteria. Finally, the application of the multi-criteria decision-making model will list the optimal strategies according to their rankings in the model. The results showed that the most important perspective is ‘benefits’, the most crucial criterion of the 20 criteria is ‘economic and financial benefits’, and the best strategy is ‘in-house’. Thus, when a business in the upstream of the SEI applies the model, the business will reveal that its optimal strategy for recycling and waste disposal shall be in-house treatment at the collection stage. These research results can provide both academic supports to the decision-makers in the upstream of the SEI and valuable guidance for evaluating their recycling programmes to obtain optimal strategies in their actual administration of the recycling practices.

13/02586 Assessment of liquid fuel (bio-oil) production from waste fish fat and utilization in diesel engine

Geo Varuvel, E. *et al. Applied Energy*, 2012, 100, 249–257.

Increased acceptance of climate change induced by human activities and raising oil demand with unsecure deliverance compels the searching for alternative fuels. The problems with environmental degradation due to industrial wastes can be reduced by converting some of them into bio-oil. In the present work, the waste from fish processing industry is converted to bio-oil by catalytic cracking. Experiments were conducted in a direct injection diesel engine of 4.5 kW at 1500 rpm. The different test fuels of diesel, fish oil at 75 °C, bio-oil UD (undistilled bio-oil), B20D80 (20% bio-oil in fossil diesel), B80D20 (80% bio-oil in fossil diesel) and neat bio-oil were tested to assess the suitability in diesel engines through combustion, emission and performance characteristics. Experimental results show that the brake thermal efficiency is marginally higher with neat bio-oil over other test fuels. It is lower with preheated fish oil and it is almost same for both bio-oil and bio-oil UD. NO_x, HC, CO and PM emissions are higher with bio-oil UD compared to bio-oil. PM, CO and HC emissions are lower with bio-oil over diesel. NO_x emissions are lower with bio-oil compared to bio-oil UD but it is still higher than diesel fuel. Addition of diesel with bio-oil reduces the NO_x emissions marginally. Intensity of premixed combustion is strong with bio-oil. Ignition delay and combustion duration are reduced with bio-oil due to high cetane number and oxygen concentration. Bio-oil from waste fish fat by catalytic cracking can be used as a fuel for diesel engines and also the waste to energy may reduce the environmental and climate change issues due to industrial wastes.

13/02587 Characterisation of waste derived intermediate pyrolysis oils for use as diesel engine fuels

Yang, Y. *et al. Fuel*, 2013, 103, 247–257.

This paper studies the characteristics of intermediate pyrolysis oils derived from sewage sludge and de-inking sludge (a paper industry residue), with a view to their use as fuels in a diesel engine. The feedstocks were dried and pelletized, then pyrolysed in the Pyroformer intermediate pyrolysis system. The organic fraction of the oils was separated from the aqueous phase and characterized. This included elemental and compositional analysis, heating value, cetane index, density, viscosity, surface tension, flash point, total acid number, lubricity, copper corrosion, water, carbon residue and ash content. Most of these results are compared with commercial diesel and biodiesel. Both pyrolysis oils have high carbon and hydrogen contents and their higher heating values compare well with biodiesel. The water content of the pyrolysis oils is reasonable and the flash point is found to be high. Both pyrolysis oils have good lubricity, but show some corrosiveness. Cetane index is reduced, which may influence ignition. Also viscosity is increased, which may influence atomization quality. Carbon residue and ash content are both high, indicating potential deposition problems. Compared with de-inking sludge pyrolysis oil, sewage sludge pyrolysis oil has a higher heating value, but higher corrosiveness and viscosity. The conclusions are that both intermediate pyrolysis oils will be able to provide sufficient heat when used in diesel engine; however poor combustion and carbon deposition may be encountered. Blending of these pyrolysis oils with diesel or biodiesel could overcome these problems and is recommended for further investigation.

13/02588 Experimental study on catalytic steam gasification of municipal solid waste for bioenergy production in a combined fixed bed reactor

Li, J. *et al. Biomass and Bioenergy*, 2012, 46, 174–180.

The catalytic steam gasification of municipal solid waste (MSW) for hydrogen-rich fuel gas production was experimentally investigated in a combined fixed bed reactor using the newly developed tri-metallic catalyst. The results indicated that the supported tri-metallic catalyst had a high activity of cracking tar and hydrocarbons, upgrading the gas quality, as well as yielding a high hydrogen production in catalytic steam gasification of municipal solid waste. A series of experiments have been performed to explore the effects of catalyst presence, catalyst to MSW mass ratio (C/M), catalytic temperature, steam to MSW ratio (S/M) and MSW particle size on the composition and yield of gasification gases. The experiments demonstrated that temperature was the most important factor in this process; higher temperature contributed to more hydrogen production and gas yield. Varying catalyst to MSW mass ratio (C/M) demonstrated complex effects on gas yield and composition of MSW gasification and an optimal value of 0.5 was found in the present study. Comparing with MSW catalytic gasification, the introduction of steam improved gas quality and yield, the optimal value of S/M was found to be 1.33 under the present operating condition. It was also shown that a smaller particle size was more favourable for gas quality and yield.

13/02589 Fuel conservation and emission reduction through novel waste heat recovery for internal combustion engines

Will, W. *Fuel*, 2012, 102, 247–255.

Lubrication systems of combustion engines offer a large potential for energy conservation and reduction of emissions. Different approaches include variable oil pumps to adjust oil pressure and flow rates to the engines requirements or thermal management to reduce the viscosity of the engine oil. For both of these systems the fuel conservation during physical tests is typically much smaller than the predictions through computations. The root cause of these differences between simulations and test results are analysed in this paper with specific focus on the heat transfer from the engine to the lubrication oil and the effects of water condensation in the exhaust. The analysis resulted in different waste heat recovery system configurations that are presented. Vehicle test results for one system with a gasoline engine demonstrate a fuel conservation potential of over 7% together with two digit reductions of several emission components. For another more effective but also more simple system configuration a similar improvement potential is shown. Within this paper, risks and benefits of such novel waste heat recovery systems are discussed. Further benefits are the positive effects on performance, reduction of wear and the potential of extended oil change intervals.

13/02590 Heat transfer analysis of a finned-tube evaporator for engine exhaust heat recovery

Zhang, H. G. *et al. Energy Conversion and Management*, 2013, 65, 438–447.

The organic Rankine cycle (ORC) can be used to recover waste heat from an internal combustion engine. In such a system, the evaporator design is critical. Determining the amount of heat that can be transferred in a designed evaporator is extremely important for a successful ORC system. In this paper, the performance of a finned-tube evaporator used to recover exhaust waste heat from a diesel engine is presented. First, the exhaust heat of the chosen diesel engine is evaluated based on the measured data. Subsequently, a mathematical model of the evaporator is created based on the detailed geometry and the specific ORC working conditions. Then, the heat transfer of the evaporator is estimated as the diesel engine runs through all of its operating regions defined by the engine speed and the engine load. The results show that the exhaust temperature at the evaporator outlet increases with engine speed and engine load. Although the convective heat transfer coefficient of the organic working fluid is significantly larger than that of the exhaust gas, the overall heat transfer coefficient is slightly greater than that of the exhaust gas. Furthermore, the heat transfer rate is the greatest in the preheated zone and least in the superheated zone. Consequently, the heat transfer area for the preheated zone is nearly half of the total area. In addition, the area of the superheated zone is slightly greater than that of the two-phase zone. It is concluded that the heat transfer area for a finned tube evaporator should be selected carefully based on the engine's most typical operating region.

13/02591 Implementation and evaluation of a low temperature waste heat recovery power cycle using NH_3 in an organic Rankine cycle

Öhman, H. *Energy*, 2012, 48, (1), 227–232.

With increasing cost for power generation opportunities for small scale power generation from waste heat have increased. The awareness of untapped resources such as local waste heat streams as well as the available range of technology and products to harvest such streams is increasing steadily though field data is scarce for applications below 100 °C entry temperature. ORC applications have a large number of open parameters and therefore require field data for correlation of models. This paper presents field data and analysis of an ORC power generation plant operating with NH_3. The unit operates on waste heat from a Swedish pulp mill at an available temperature of 75 to 85 °C. Performance at varying heat source conditions and capacity is reported as well as an analysis of the particular investment case. The data was generated during a 15-day period and show a thermal efficiency of 8–9% at capacities from 50 to 100%. The results indicate a flat thermal efficiency from 20 to 100% capacity. Investment case analysis is based on a purchase model while the chosen economic model is a supplier own-and-operate arrangement supplying the mill with power at a predefined cost during an extended period of time.

13/02592 Industrial eggshell wastes as the heterogeneous catalysts for microwave-assisted biodiesel production

Khemthong, P. *et al. Catalysis Today*, 2012, 190, (1), 112–116.

Active biodiesel production catalysts were derived from waste eggshells by simple calcination in air. The physicochemical properties of the activated catalysts were characterized by XRD, N_2 sorption, CO_2-TPD, TGA–DTG, XRF, and SEM, while the catalytic activity was tested in producing biodiesel via transesterification on palm oil with methanol under microwave conditions. The effect of microwave power, reaction time, methanol-to-oil ratio, and catalyst loading was investigated. The experimental results revealed that the catalysts exhibited a high content of CaO (99.2 wt%) with a high density of strong base sites. The catalytic testing demonstrated a remarkable enhancement for biodiesel production using microwaves compared to conventional heating. The maximum yield of fatty acid methyl esters reached 96.7% under the optimal condition of reaction time of 4 min with 900 W microwave power, methanol-to-oil ratio of 18:1, and catalyst loading of 15%. The results indicated that the CaO catalysts derived from eggshells showed good reusability and had high potential to be used as biodiesel production catalysts under microwave-assisted transesterification of palm oil.

13/02593 Investigation of the possibility of using waste cooking oil as a rejuvenating agent for aged bitumen

Zargar, M. *et al. Journal of Hazardous Materials*, 2012, 233–234, 254–258.

The ageing of the bitumen during storage, mixing, transport and laying on the road, as well as in service life, are the most important problems presented by the use of bitumen in pavements. This paper investigates the possibility of using waste cooking oil (WCO), which is a waste material that pollutes landfills and rivers, as an alternative natural rejuvenating agent for aged bitumen to a condition that resembles the original bitumen. With this target, the physical and chemical properties of the original bitumen, aged bitumen and rejuvenated bitumen were measured and compared by the bitumen binder tests – softening point, penetration, Brookfield viscosity, dynamic shear rheometer and Fourier transform infrared spectroscopy. In addition, the behaviour of the WCO rejuvenated bitumen is investigated and compared with virgin bitumen after using the rolling thin film oven ageing process. In general, the results showed that using 3–4% of WCO the aged bitumen group 40/50 was rejuvenated to a condition that closely resembled the physical, rheological properties of the original bitumen (80/100), however, there was a difference in the tendency to ageing between the WCO rejuvenated bitumen and the virgin bitumen during mixing, transport and laying on the road.

13/02594 Optimization of biohydrogen and methane recovery within a cassava ethanol wastewater/waste integrated management system

Wang, W. *et al. Bioresource Technology*, 2012, 120, 165–172.
Thermophilic co-fermentation of cassava stillage (CS) and cassava excess sludge (CES) were investigated for hydrogen and methane production. The highest hydrogen yield (37.1 ml/g-total-VS added) was obtained at VS_{CS}/VS_{CES} of 7:1, 17% higher than that with CS digestion alone. The CES recycle enhanced the substrate utilization and improved the buffer capacity. Further increase the CES fraction led to changed VFA distribution and more hydrogen consumption. FISH analysis revealed that both hydrogen producing bacteria and hydrogen consuming bacteria were enriched after CES recycled, and the acetobacteria percentage increased to 12.4% at VS_{CS}/VS_{CES} of 6:2. Relatively high efficient and stable hydrogen production was observed at VS_{CS}/VS_{CES} of 5:3 without pH adjusted and any pretreatment. The highest total energy yield, the highest COD and VS degradation were obtained at VS_{CS}/VS_{CES} of 7:1. GFC analysis indicated that the hydrolysis behaviour was significantly improved by CES recycle at both hydrogen and methane production phase.

13/02595 Optimization of fuel production from waste vehicle tires by pyrolysis and resembling to diesel fuel by various desulfurization methods

Aydin, H. and Ilkiliç, C. *Fuel*, 2012, 102, 605–612.
In this study, an alternative fuel for diesel engines was produced from waste automobile tyres by the method of pyrolysis. In order to reduce the high sulfur content of the fuel, CaO, $Ca(OH)_2$, and NaOH catalysts were used. In addition, effects of variables such as temperature, the catalyst ratio and the N_2 flow rate on yield were investigated. The highest product yield was obtained with temperature of 500 °C and 200 cm^3/min N_2 flow rate. When compared with the products obtained from initial pyrolysis, the sulfur content of the product was found to be 34.25% lower with the utilization of 5% $Ca(OH)_2$ in the reaction. In order to make the sulfur content of the product closer diesel fuel, the acetic acid–H_2O_2, formic acid–H_2O_2 and H_2SO_4 were used in different proportions. Although, the other acids were also very effective, the use of 10% H_2SO_4 reduced sulfur content of the product by 75.27%. Thus, with 5% $Ca(OH)_2$ and then with addition of 10% H_2SO_4, the sulfur content of the product was reduced by 83.75%. The properties of diesel fuel (DF), liquid fuel derived from waste vehicle tyres (TF), low-sulfur tyre fuel (LSTF) and fuel mixtures of LSTF–DF were analysed. It was found that, the density and sulfur content of LSTF fuel were slightly higher than that of diesel fuel, but other features and distillation curves were very close to diesel fuel.

13/02596 Performance analysis of double organic Rankine cycle for discontinuous low temperature waste heat recovery

Wang, D. *et al. Applied Thermal Engineering*, 2012, 48, 63–71.
This research proposes a double organic Rankine cycle (ORC) for discontinuous waste heat recovery. The optimal operation conditions of several working fluids have been calculated by a procedure employing MATLAB and REFPROP. The influence of outlet temperature of heat source on the net power output, thermal efficiency, power consumption, mass flow rate, expander outlet temperature, cycle irreversibility and exergy efficiency at a given pinch point temperature difference (PPTD) has been analysed. Pinch point analysis has also been employed to obtain a thermodynamic understanding of the ORC performance. Of all the working fluids investigated, some performances between each working fluid are rather similar. For a fixed low temperature heat source, the optimal operation condition should be mainly determined by the heat carrier of the heat source, and working fluids have limited influence. Lower outlet temperature of heat source does not always mean more efficient energy use. Acetone exhibits the least exergy destruction, while R245fa possesses the maximal exergy efficiency at a fixed PPTD. Wet fluids exhibit lower thermal efficiency than the others with the increasing of PPTD at a fixed outlet temperature of heat source. Dry and isentropic fluids offer attractive performance.

13/02597 Study on pyrolysis characteristics of refuse plastic fuel using lab-scale tube furnace and thermogravimetric analysis reactor

Park, S. S. *et al. Journal of Analytical and Applied Pyrolysis*, 2012, 97, 29–38.
Product yields of liquid, solid, and gas were obtained from pyrolysis experiments on refuse plastic fuel (RPF) using a tube furnace in a nitrogen atmosphere under three non-isothermal conditions (maximum temperature: 400, 600 and 800 °C). And, the effect of the temperature on the product yields of liquid, solid and gas were discussed. The gas compositions and liquid compounds were analysed using gas chromatography (GC) and gas chromatography mass spectrum detector (GC–MSD), respectively. Using a thermogravimetric analysis (TGA) reactor, thermal decomposition characteristics of PS, PVC, LDPE, and PP as well as RPF during pyrolysis were analysed. Using the single reaction model, the activation energy and pre-exponential factor for RPF pyrolysis were 211.11 kJ/mol and 9.04E+13 l/min, respectively. Using the parallel reaction model, the activation energies of PS, PP, LDPE, $PVC_{\{1\}}$ and $PVC_{\{2\}}$ (subscripts {1} and {2} refer to the first and second degradation of PVC in mass) were 231.83, 193.55, 175.92, 72.6, and 164.94 kJ/mol, respectively, and their pre-exponential factors were 2.27E+17, 4.49E+13, 7.09E+11, 1.24E+06 and 2.16E+11 l/min, respectively.

13/02598 The feasibility of biodiesel production by microalgae using industrial wastewater

Wu, L. F. *et al. Bioresource Technology*, 2012, 113, 14–18.
This study investigated nitrogen and phosphorus assimilation and lipid production of microalgae in industrial wastewater. Two native strains of freshwater microalgae were evaluated their biomass growth and lipid production in modified BBM medium. *Chlamydomonas* sp. TAI-2 had better biomass growth and higher lipid production than *Desmodesmus* sp.TAI-1. The optimal growth and lipid accumulation of *Chlamydomonas* sp. TAI-2 were tested under different nitrogen sources, nitrogen and CO_2 concentrations and illumination period in modified BBM medium. The optimal CO_2 aeration was 5% for *Chlamydomonas* sp. TAI-2 to achieve maximal lipid accumulation under continuous illumination. Using industrial wastewater as the medium, *Chlamydomonas* sp. TAI-2 could remove 100% NH_4^+-N (38.4 mg/L) and NO_3^--N (3.1 mg/L) and 33% PO_4^{3-}-P (44.7 mg/L) and accumulate the lipid up to 18.4%. Over 90% of total fatty acids were 14:0, 16:0, 16:1, 18:1, and 18:3 fatty acids, which could be utilized for biodiesel production.

13/02599 The potential of (waste)water as energy carrier

Frijns, J. *et al. Energy Conversion and Management*, 2013, 65, 357–363.
Next to energy efficiency improvements in the water sector, there is a need for new concepts in which water is viewed as a carrier of energy. Municipal wastewater is a potential source of chemical energy, i.e. organic carbon that can be recovered as biogas in sludge digestion. The recovery of chemical energy can be maximized by up-concentration of organic carbon and maximized sludge digestion or by source separation and anaerobic treatment. Even more so, domestic wastewater is a source of thermal energy. Through warm water conservation and heat recovery, for example with shower heat exchangers, substantial amounts of energy can be saved and recovered from the water cycle. Water can also be an important renewable energy source, i.e. as underground thermal energy storage. These systems are developing rapidly in the Netherlands and their energy potential is large.

13/02600 Transesterification of waste cooking oil: process optimization and conversion rate evaluation

Abd Rabu, R. *et al. Energy Conversion and Management*, 2013, 65, 764–769.
Biodiesel is a mono-alkyl ester of vegetable oil, animal fat, and recycled cooking oil. It is gaining importance in the quest of finding sustainable fuel as it is compatible with petrodiesel and its synthesis process is becoming more commercially deployable. It is commonly prepared by the transesterification of triglycerides or the esterification of free fatty acid with methanol by stirring and accelerated by the presence of base or acidic catalyst. In this work biodiesel was produced by transesterification of waste cooking oil (WCO) following different process settings with the objective to achieve maximum yield and purity. Due to immiscibility and reaction reversibility, high purity WCO biodiesel of 95% was produced at 12:1 alcohol to oil molar ratio at 1% w/w NaOH catalyst and under continuous mixing of 2 h at 60 °C. Chemical kinetics was determined for the optimal process and found to follow first-order reaction rate with a rate constant ranges from 0.0035 to 0.0106 min^{-1}. The activation energy was also evaluated by running the experiment at three different temperatures and found to be near 25,496 J/mol. The distillation curve and properties of the resulted fuel was also assessed and were compared plausibly to ASTM biodiesel standards. Furthermore, the emitted soot from a diffusion wick flame was measured via opacity meter and clearly show the advantage of the biodiesel with a nearly an order of magnitude lower.

13/02601 Using the analytic network process (ANP) to determine method of waste energy recovery from engine

Liang, X. *et al. Energy Conversion and Management*, 2013, 66, 304–311.
There are many ways to recover engine waste energy. But which way is the most suitable or feasible ways in future? This is belongs to a multi-criteria decision-making (MCDM) process. Existing methods for project selection does not reflect interdependencies of criteria and candidate methods. Consideration of criteria interdependencies enables valuable cost savings and great benefits to engine and environment. When these problems are evaluated, it is necessary to collect group opinion because the interdependence relationship among criteria is known and it is very important to consider the criteria for the problem solving and decision-making. In order to collect group opinions for interdependent project problems, expert interviews are

conducted. Analytic network process (ANP) is applied for measurement of the dependency among the strategic factors, which can help engineer determine their decisions. It is found that thermoelectricity technology is the most suitable method to recovery waste energy in future and the ANP technique is useful as a decision judgement tool.

13/02602 Waste thermal energy harvesting from a convection-driven Rijke–Zhao thermo-acoustic-piezo system

Zhao, D. *Energy Conversion and Management*, 2013, 66, 87–97.

In this work, a convection-driven Rijke–Zhao thermo-acoustic-piezo system is designed and experimentally tested to demonstrate its potential for harvesting thermal energy. For this, a non-linear theoretical model is developed to simulate the energy conversion process, i.e. heat-to-sound-to-electricity in the present system. Unlike the conventional conduction-driven thermoacoustic converters, this system involves no heat exchangers and stacks. As a heat source is placed in a Rijke–Zhao tube with two bifurcating daughter branches, self-sustained thermoacoustic oscillations are generated. The resulting acoustic fields in the bifurcating branches are dramatically different. One branch is associated with ‘hot’ oscillations. However the other is with ‘cold’ oscillations at ambient temperature, which enable a piezoelectric generator being implemented to the end of the branch. In order to measure the acoustic fields in the bifurcating branches, two arrays of thermocouples and microphones are used. The maximum sound pressure level is around 139 dB. The output electric power and acoustical energy conversion efficiency are measured and compared with that from a similar but a conduction-driven thermo-acoustic-piezo system. It is found that 60% more power is generated. And the energy conversion efficiency is increased by 105%. These experimental results confirm that the developed Rijke–Zhao thermo-acoustic-piezo system is an invaluable tool in designing a simple, low-cost, energy-efficient thermoacoustic system.

13/02603 Wet ethanol in HCCI engines with exhaust heat recovery to improve the energy balance of ethanol fuels

Saxena, S. *et al. Applied Energy*, 2012, 98, 448–457.

This study explores the use of wet ethanol as a fuel for HCCI engines while using exhaust heat recovery to provide the high input energy required for igniting wet ethanol. Experiments were conducted on a four-cylinder Volkswagen engine modified for HCCI operation and retrofitted with an exhaust gas heat exchanger connected to one cylinder. Tested fuel blends ranged from 100% ethanol to 80% ethanol by volume, with the balance being water. These blends are directly formed in the process of ethanol production from biomass. Comprehensive data was collected for operating conditions ranging from intake pressures of 1.4–2.0 bar and equivalence ratios from 0.25 to 0.55. The heat exchanger was used to preheat the intake air allowing HCCI combustion without electrical air heating. The results suggest that the best operating conditions for the HCCI engine and heat exchanger system in terms of high power output, low ringing, and low nitrogen oxide emissions occur with high intake pressures, high equivalence ratios, and highly delayed combustion timings. Removing the final 20% of water from ethanol is a major energy sink. The results of this study show that HCCI engines can use ethanol fuels with up to 20% water while maintaining favourable operating conditions. This can remove the need for the most energy-intensive portion of the water removal process.